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DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
BUREAU OF MINES
VAN. H. MANNING, DIRECTOR

APPROVED EXPLOSION-PROOF COAL-CUTTING EQUIPMENT

BY

L. C. ILSLEY AND E. J. GLEIM

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CONTENTS.

	Page.
Introduction	5
Acknowledgments	6
Theory of fire damp protection	6
Occurrence of methane	6
Explosive limits of fire damp	7
Ignition temperature of methane	7
Presence of fire damp in electrical apparatus	7
Conditions necessary for explosion	8
Factors bearing on safety	8
Spread of explosions from unprotected apparatus	8
Spread of explosions from damaged apparatus	8
Spread of explosions through openings in apparatus	8
Effect of internal spacing on internal pressure	9
Explosion pressures of mixtures of gas and air	9
Effect of coal dust in the apparatus	10
Construction of equipment	11
Gas-tight apparatus	11
Totally inclosed apparatus	11
Partly inclosed apparatus	11
General rules for construction	12
Construction of protective devices	12
Wire gauze protection	12
Plate protection	13
General requirements	13
Schedules issued for testing explosion-proof equipment	14
Procedure for establishing a list of permissible explosion-proof electric motors	14
General statement	14
Definition of "explosion proof"	14
Definition of "permissible"	14
Conditions under which motors will be tested	14
Requirements for approval of motors	15
Construction	15
Controlling appliances	16
Motor casing	16
Cable reel and trailing cable	16
Character of tests to which motors will be subjected	17
Caution and approval plates	17
Notification of manufacture	19
Drawings of approved motors to be filed	19
Scope of approval	19
Withdrawal of approval	19
Tests of storage-battery locomotives	19

Schedules issued for testing explosion-proof equipment—Continued.
Procedure for establishing a list, etc.—Continued. Page.
Fees for testing explosion-proof motors, coal-cutting equipments, and locomotives 19
Complete tests 19
Extra tests involving no preparation 20
Special tests involving preparation of equipment 20
Tests of storage-battery locomotives 20
Synopsis of procedure to be followed in making application for tests, submitting material, conducting tests, and notifying applicant of results 20
Gas and equipment used 21
Gas 21
Testing equipment 21
Explosion chamber 21
Fan and circulating system 22
Switchboard 22
Crane 24
Application of Schedule 2A to the testing of commercial equipment 24
Assistance rendered by the manufacturer 24
Factors causing delay 24
Drawings 25
Inspection and maintenance of approved equipment 25
Equipments approved and description of tests 26
Approvals granted under Schedules 2 and 2A 26
Approved equipments 26
Test procedure 26
Sullivan direct-current coal-cutting equipments, approvals Nos. 100 and 100A 27
Description of CE–7 direct-current equipments 28
Motor 28
Controller and starting rheostat 28
Cable reel 28
Safety features 29
Investigation of 250-volt equipment 29
Preliminary inspection and recommendations 29
Nature of tests 29
Explosion pressures obtained 31
Changes in design 31
Investigation of the 500-volt equipment 32
Summary 32
Goodman direct-current coal-cutting equipments, approvals Nos. 101 and 101A 32
Description of 23-C direct-current equipment 33
Motor 33
Controller and starting rheostat 33
Cable reel and truck with fuse and switch 33
Fuse and switch 33
Safety features 34
Investigation of 210-volt equipment 35
Preliminary inspection and recommendations 35
Nature of tests 35
Explosion pressures obtained 35
Changes in design 36

Equipments approved and description of tests—Continued.
Goodman direct-current coal-cutting equipments—Continued. Page.
Investigation of 500-volt equipment 36
Summary 36
Jeffrey direct-current coal-cutting equipments, approvals Nos. 102 and 102A 36
Description of 28-A direct-current equipment 37
Motor 37
Controller and starting rheostat 37
Cable reel and truck with fuse and switch 37
Safety features 38
Investigation of 250-volt equipment 38
Preliminary inspection and recommendations 38
Nature of tests 39
Explosion pressures obtained 39
Changes in design 39
Investigation of 500-volt equipment 39
Summary 40
Jeffrey direct-current coal-cutting equipments, approvals Nos. 103 and 103A 40
Description of 35–B direct-current equipments 40
Motor 40
Controller and starting rheostat 40
Cable reel and truck with fuse and switch 41
Safety features 41
Investigation of 250-volt equipment 41
Preliminary inspection and recommendations 41
Nature of tests 42
Explosion pressures obtained 42
Changes in design 42
Investigation of 500-volt equipment 42
Summary 43
Sullivan alternating-current coal-cutting equipments, approvals Nos. 104 and 104A 43
Description of CE–7 alternating-current equipments 43
Motor 43
Controller and fuse compartments 43
Cable reel 44
Safety features 44
Investigation of 440-volt equipment 45
Preliminary inspection and recommendations 45
Nature of tests 45
Explosion pressures obtained 46
Changes in design 46
Investigation of 220-volt equipment 46
Summary 47
Résumé 47
Publication on coal mining 49

ILLUSTRATIONS.

Page.

PLATE I. *A*, Explosion-proof motor testing gallery closed for tests; *B*, Gallery open for airing 22

II. *A*, Circulating fan with motor and parts of piping system; *B*, Switchboard and control appliances 23

III. *A*, Sullivan CE–7 direct-current machine; *B*, Sullivan CE–7 direct-current machine, motor removed and controller compartment open for inspection 28

IV. Sullivan CE–7 direct-current machine, rear head removed to the right and rheostat compartment open for inspection 29

V. *A*, Sullivan CE–7 direct-current cable reel; *B*, Sullivan CE–7 direct-current cable reel, partly dismantled for inspection 30

VI. *A*, Sullivan CE–7 direct-current machine, front head with one element of protective device removed; *B*, Sullivan CE–7 direct-current machine, rear head with one element of protective device removed 31

VII. *A*, Goodman 23–C direct-current machine; *B*, Goodman, 23–C direct-current cable reel and truck 32

VIII. Goodman 23–C direct-current machine, open for inspection of rheostat, controller, armature, and protective devices 33

IX. Goodman 23–C direct-current cable reel and truck, explosion-proof compartment open to show underside of protective device grid and details of switch and fuse 34

X. *A*, Jeffrey 28–A direct-current machine; *B*, Jeffrey cable reel and switch for 28–A and 35–B direct-current machines 36

XI. Jeffrey 28–A direct-current machine. Details of construction 37

XII. Jeffrey 28–A direct-current machine. Further details of construction 38

XIII. *A*, Jeffrey 28–A and 35–B direct-current cable reel and switch. Compartment for switch and fuse open for inspection; *B*, Jeffrey 28–A and 35–B direct-current cable reel and switch; terminal compartment open for inspection 39

XIV. *A*, Jeffrey 35–B direct-current machine; *B*, Jeffrey 35–B direct-current machine; rheostat compartment open for inspection 40

XV. Jeffrey 35–B direct-current machine, motor and controller compartments open for inspection 41

XVI. *A*, Sullivan CE–7 alternating-current machine; *B*, Sullivan CE–7 alternating-current machine; front head with both elements of protective device removed 42

XVII. *A*, Sullivan CE–7 alternating-current machine, motor removed; rear head in the background and controller compartment open for inspection. *B*, Sullivan CE–7 alternating-current machine; switch and fuse compartment open for inspection 43

XVIII. *A*, Sullivan CE–7 alternating-current machine; *B*, Sullivan CE–7 alternating-current cable reel dismantled to show interior of slip-ring compartment and details of disconnecting plug 44

FIGURE 1. Elevation of testing apparatus 23

2. Paths of burned gases discharged through protective devices of Sullivan CE–7 explosion-proof motors 30

3. Path of burned gases discharged through protective devices of Goodman 23–C explosion-proof motor 34

APPROVED EXPLOSION-PROOF COAL-CUTTING EQUIPMENT.

By L. C. Ilsley and E. J. Gleim.

INTRODUCTION.

Electrical apparatus because of its flexibility and its adaptability to all classes of service has become essential to the mining industry. Hence the problem of providing electrical equipment that is safe for use in explosive mixtures of methane and air is of prime importance in coal mining. Investigators and experiment stations early recognized this fact and much work has been done in the investigation and the development of electrical apparatus for use in atmospheres containing fire damp. The term "fire damp" as applied throughout this bulletin means an explosive mixture of methane and air.

Direct-current motors and alternating-current motors of the slip-ring type when running usually give off electric arcs or flashes that will ignite fire damp. Other motors that have no moving electric contacts may become dangerous through accident, deterioration, or neglect. Auxiliary apparatus such as fuses, switches, rheostats, and controllers may arc, flash, or become heated to such a degree that fire damp can be ignited. Such equipment is still more dangerous when worn or out of repair.

In the United States the development of apparatus for use in gaseous mines has been associated largely with coal-cutting equipment run by electricity. This is undoubtedly due to the use of such equipment at the face of the mine workings, where the chance of igniting fire damp is necessarily greatest. One American manufacturer built a coal-cutting equipment of the totally inclosed type for use in fire damp atmospheres in 1903. Another built similar equipment with special protective devices in 1906, for export.

During the years 1910 and 1911, the Bureau of Mines at its Pittsburgh experiment station conducted a preliminary investigation of the safety of such protection as was then in use or under consideration. Five motors were submitted for this investigation, each having somewhat different methods of protection. The results of this investigation were published in Bulletin No. 46.[a]

[a] Clark, H. H., Investigation of explosion-proof motors, Bull. 46, Bureau of Mines, 1912, 44 pp.

Although none of the motors tested met all the conditions for safety, the investigation was of value in laying the foundation for future tests and development. Based on the experience gained a schedule of tests was published by the bureau that stated the fees and requirements for the test of motors designed for use in gaseous mines and also stated that the bureau would give its seal of approval to such motors as met the requirements.

The first part of the present bulletin deals with the general theory of protection from fire damp, gives the bureau's schedule, and shows its application to the testing of commercial apparatus. The second part covers a detailed description of the apparatus that has been tested and approved under this schedule, together with a résumé of the tests on which the approvals were based.

ACKNOWLEDGMENTS.

Acknowledgment is made of the helpful cooperation that has been given by the manufacturers of the various equipments investigated. Acknowledgment of the gift of a new testing gallery is made to the following manufacturers of mining equipment: Jeffrey Manufacturing Co., Columbus, Ohio; Goodman Manufacturing Co., Chicago, Ill.; Morgan-Gardner Electric Co., Chicago, Ill.; Sullivan Machinery Co., Claremont, N. H.; and Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa. This gallery (see detailed description under Testing Equipment, p. 21) was built and installed by the Jeffrey Manufacturing Co. The storage battery used in connection with the outfit was donated by the Edison Storage Battery Co., of Orange, N. J.

The investigation herein reported was begun under the direction of H. H. Clark, assisted by R. W. Crocker and O. I. Gaines, and was continued by the authors.

THEORY OF FIRE DAMP PROTECTION.

OCCURRENCE OF METHANE.[a]

Ordinarily, the only gas that occurs in coal mines in sufficient quantities to cause an explosion is methane, CH_4. This gas is so prevalent throughout the coal-mining regions of the United States that mechanical ventilation is generally necessary to prevent the accumulation of dangerous percentages of methane in the mine air. Effort is made to dilute the mine atmosphere with fresh air so that the methane content does not exceed one-half of 1 per cent in return air currents. Frequently, because of improper systems of ventilation or accidental interruption of proper systems, or because of the release

[a] Darton, N. H., Occurrence of explosive gases in coal mines, Bull. 72, Bureau of Mines, 1915, p. 248.

of abnormal quantities of gas, enough methane accumulates in a given place to make the atmosphere of that place explosive.

EXPLOSIVE LIMITS OF FIRE DAMP.

The lower explosive limit of methane[a] is reached when the proportion is about 5.5 per cent of methane mixed with 94.5 per cent of air. The upper explosive limit is about 14.5 per cent of methane to 85.5 per cent of air. Below or above this explosive range the methane is only partly burned when the mixture is ignited.

Percentages of methane under 5.5 per cent, when mixed with large volumes of coal dust in suspension, make a mine atmosphere more dangerous than when it contains coal dust alone.

IGNITION TEMPERATURE OF METHANE.

Methane is ignited at about 650° C.[b] This gas does not ignite as readily as hydrogen and several other gases, but must be heated to ignition temperature for an appreciable time before it ignites. Therefore, flames of somewhat higher temperature than that at which methane ignites may momentarily pass into this gas without causing an ignition. However, the temperature resulting from sparks, flashes, incandescent filaments, or other electric activity usually so far exceeds the ignition temperature of methane (650° C.) that when fire damp is present an explosion is almost sure to result.

PRESENCE OF FIRE DAMP IN ELECTRICAL APPARATUS.

Fire damp is likely to enter the interior of electrical apparatus that has openings of sufficient size to permit diffusion of the methane with the air. This diffusion will take place readily if the apparatus is allowed to remain in a room filled with fire damp for several hours. Apparatus of the totally-inclosed type is much less liable to be a source of danger through diffusion of methane than apparatus of the former type. Diffusion, however, is not the only way in which fire damp enters the interior of apparatus. The metallic parts of electrical apparatus are subject to variations of temperature during periods of rest and operation. Consequently the atmosphere within expands and contracts, creating an unbalanced pressure with the atmosphere outside. This difference of pressure tends to become equalized by the transfer of gases in and out of the casing. Thus fire damp may be drawn into the interior of an electric motor, or other electric equipment, through very small openings.

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[a] Burrell, G. A., and Oberfell, G. G., The limits of inflammability of mixtures of methane and air, Tech. Paper 119, Bureau of Mines, 1915, p. 30. Burrell, G. A., and Gauger, A. W., Limits of complete inflammability of mixtures of mine gases and of industrial gases with air, Tech. Paper 150, Bureau of Mines, 1917, p. 13.

[b] Dixon, H. B., and Coward, H. F., The ignition temperature of gases, Chem. News, March 19, 1909, vol. 99, p. 139.

CONDITIONS NECESSARY FOR EXPLOSION.

The basic conditions that bring about a mine explosion having its ignition from an electrical source are as follows: The presence of fire damp in the immediate vicinity of the apparatus, the penetration by diffusion or otherwise of the fire damp into the apparatus, and the ignition of the fire damp by an electric spark, flash, or other means.

FACTORS BEARING ON SAFETY.

The hazard introduced with the use of a piece of electrical apparatus in a gaseous mine, and the possible results of an explosion within that apparatus, depend upon the following factors: Lack of protection, weak mechanical construction, incorrect ideas of what constitutes adequate protection, the amount and arrangement of the internal unoccupied space, the compression of the gas within the machine, and the percentage of gas and the amount and distribution of coal dust.

SPREAD OF EXPLOSIONS FROM UNPROTECTED APPARATUS.

If the explosion is caused by unprotected apparatus the mixture surrounding the equipment can reasonably be expected to ignite. Such an outside explosion in an anthracite mine would proceed as far as the gaseous mixture extended, and in a bituminous mine, due to the explosibility of coal dust, it would probably continue throughout the mine. In either event life and property may be lost.

SPREAD OF EXPLOSIONS FROM DAMAGED APPARATUS.

If the explosion takes place within apparatus of weak mechanical construction, walls will be distorted or destroyed, bolts will be sheared, seams and joints will be opened, and the explosion will spread to the outside with the disastrous results just mentioned. Much inadequate apparatus is used in mines, because many manufacturers do not realize the necessity of providing durable, rugged equipment for all kinds of mine work. For safety devices good mechanical construction is all the more necessary. The walls of such apparatus must be strong enough to withstand internal-explosion pressures so that no path will be made whereby the flames may escape through openings and ignite possible explosive mixtures outside.

SPREAD OF EXPLOSIONS THROUGH OPENINGS IN APPARATUS.

When overlooked or accidental openings, such as free space around the wires where they enter the casing, a path through oil wells, or a path caused by the omission of a bolt or cap-screw from an unbottomed hole, an internal explosion may possibly be propagated

through these accidental openings to the outside atmosphere with the disastrous effects already mentioned.

An explosion within electric apparatus may also be propagated through intentional openings, such as relief openings and small openings between flange joints, if such openings are not properly designed so as to cool the escaping flames below the ignition temperature of fire damp.

EFFECT OF INTERNAL SPACING ON INTERNAL PRESSURE.

Not only is the strengthening of the walls and relief openings of the apparatus necessary, but particular attention should also be given to the arrangement of the internal unoccupied space. If the explosion begins at one end of a long passage, a pressure wave will precede the flame wave. As this wave advances the rapidity of combustion of the gases increases with the increase in pressure and further increases the compression of unburned gases ahead, so that when the flame wave reaches the other end of the passage the explosive mixture there is under so much pressure that when it is ignited ordinary casings will not be strong enough to withstand the resulting pressure.

The same is true if two or more compartments are connected, especially when the opening between the compartments is such as to create a considerable pressure wave in advance of the flame propagation. Therefore, long drawn-out paths should be avoided as they affect the safety of the walls and as the violence of the flame propagation may be such as to force the flames through the protective devices or the flange joints.

EXPLOSION PRESSURES OF MIXTURES OF GAS AND AIR.

The physics department of the Bureau of Mines investigated the effect of compression when explosive mixtures of natural gas and air are ignited.

A mixture containing about 8 per cent of natural gas (of the composition given on page 82) under atmospheric pressure in a small steel chamber gave a maximum pressure of 74 pounds to the square inch as measured by a Crosby gas engine indicator.

A mixture having the same percentage of gas, but under 10 to 12 pounds above atmospheric pressure, gave a maximum pressure of about 135 pounds to the square inch.

Although the above results are based on special conditions, and slight changes in temperature, size or shape of the chamber would cause considerable difference in pressures, yet with other conditions constant, a slight increase in pressure plainly has a marked effect on the violence of the explosion.

Suppose the explosion takes place in a compartment where parts, such as the armature of the motor, are in rotation, then, because of the

slight compression of the interior mixture by centrifugal force, the pressure produced by the explosion will usually be greater than that obtained when the motor is stationary. Sometimes the external gases are drawn into the motor interior immediately after an explosion and continue to burn. This action is usually termed "afterburning." If afterburning is prolonged it will seriously damage the insulation.

When the explosive mixture is composed of methane and air only, reasonably consistent results, so far as flame and explosive pressure are concerned, may be obtained, provided care is used to ignite from a given point a definite mixture that is uniformly distributed throughout the interior of the apparatus. The pressure at any given point within the apparatus will depend on where the explosion was initiated, and, to a certain degree, on proximity to relief openings. At different points the pressure is greater or less, depending on the distance the flame has traversed before reaching that point and on the arrangement of the internal unoccupied space.

If the explosive mixture in the inclosure contains between 8 and 9 per cent of methane, the explosion will be most violent, but not necessarily most liable to cause an exterior explosion,[a] as experiments have demonstrated that a lower percentage of gas will cause flames to pass more easily through holes or gauze-type protective devices.

EFFECT OF COAL DUST IN THE APPARATUS.

Coal dust may be present in the gaseous mixture as a dust cloud, the density of which is a variable quantity and difficult to measure or duplicate under commercial testing conditions. Or the dust may be in the form of a deposit, various amounts of which may be stirred up by the force of the explosion. Some of these coal particles are distilled, some are decomposed and enter into the combustion, some are driven out through the openings in an incandescent state. Tests made by the Bureau of Mines have not definitely shown that the presence of coal dust within the apparatus increases the danger of explosion. In some tests the pressure was increased. Undoubtedly the decomposition of the constituents of coal abstracts heat from the gas flames and cools them. If a dust cloud of just the proper density were present, it might conceivably increase the combustion and consequently the pressure.

In certain designs of protective devices the coal dust partly blocks the exhaust openings and increases the pressure. When incandescent

[a] von Beyling, —, Versuche zwecks Erprobung der Schlagwettersicherheit besonders geschützter elektrischer Motoren und Apparate sowie zur Ermittlung geeigneter Schutzvorrichtungen fur solche Betriebsmittel. Ausgeführt auf der berggewerkschaftlichen Versuchstrecke in Gelsenkirchen, 1906, 89 pp.

particles are forced out into the surrounding atmosphere, they cool almost instantly and are above the ignition temperature of methane for so short a time that they probably can not ignite fire damp and thus cause an explosion.

CONSTRUCTION OF EQUIPMENT.

The chief problem confronting the manufacturer of apparatus suited for fire damp atmospheres is that of extracting heat from possible explosion flames and of cooling them below the ignition temperature of methane (650° C.) as they pass through the openings. Cooling may be the result of contact of the flames with metallic joints or openings through which they pass or by sudden expansion of the gases from a comparatively high pressure within to the atmospheric pressure without, or by both. In fact, while one or the other of the above conditions may predominate, some cooling and some expansion will always take place, as the escaping flames must come in contact with the sides of the openings and the internal pressure exceeds atmospheric pressure.

Apparatus of this kind can be classified as follows: Class 1, gas-tight apparatus; class 2, totally inclosed apparatus; class 3, partly inclosed apparatus.

GAS-TIGHT APPARATUS.

Class 1 includes apparatus made with absolutely gas-tight compartments. Such apparatus is not practical for mine service, because of the difficulty of inspection and of making renewals. Moreover, the ordinary materials used in packing joints would deteriorate in a mine. Therefore, this class of equipment has been used but little.

TOTALLY-INCLOSED APPARATUS.

Class 2 includes apparatus that has no openings, except flange joints, the openings of which can be closed tight enough to prevent explosions within the apparatus from spreading to the surrounding atmosphere. Obviously, a given size of motor, when used in a totally-inclosed machine, must be rated somewhat lower than when used in one that is ventilated. Apparatus of this class has, however, the advantages of simplicity of design, slight deterioration, and freedom from excessive dust troubles.

PARTLY-INCLOSED APPARATUS.

Class 3 includes apparatus with openings that afford a certain amount of ventilation—openings in which are placed heat-abstracting devices, in this paper called "protective devices." The flange joints are of the same characteristics as those of the second class.

The design and maintenance of safe protective devices is the chief problem of apparatus of this class.

GENERAL RULES FOR CONSTRUCTION.

Apparatus for mine service should be especially strong and durable. This insures that under the severe use to which it will be subjected parts will not be distorted; that the mass will be rigid enough to permit the construction of carefully designed, machined joints; and that the casing will be strong enough mechanically to withstand any pressure that might be developed by internal explosions.

All joints between sections of compartments or between covers and compartments should be flanged joints. The surfaces of such flanges should have at all points a minimum metal-to-metal contact at least 1 inch wide.

The joints of totally inclosed apparatus or of apparatus having one or more totally inclosed compartments, require special consideration, as the pressure developed in such apparatus during an explosion is necessarily higher than in apparatus provided with relief openings. Such joints must be held together with a sufficient number of bolts or studs properly spaced and strong enough to maintain a uniform bearing. A small opening along the flange when such joints are properly designed does not necessarily make the apparatus dangerous, as, owing to the smallness of the opening, the flames are cooled both by contact with the flanges and by expansion as they pass to the surrounding atmosphere.

CONSTRUCTION OF PROTECTIVE DEVICES.

WIRE GAUZE PROTECTION.

The earliest protective device known is wire gauze, used by Sir Humphrey Davy and his contemporaries on the miners' flame safety lamp. From its long use on such lamps this type of protection is well known. The gauze gives excellent protection for the small volume of gas found in an ordinary flame lamp, especially if the lamp is provided with a shield that prevents direct impact of moving currents of fire damp on the gauze.

Motors and other apparatus usually have much more unoccupied space, and therefore require many layers of gauze of considerable area. Owing to the lack of mechanical strength, gauze of this area must have reinforcement in order that the device can withstand explosion pressures. The layers of gauze are usually separated by metal grids or punchings that serve as spacers and supports for the gauze. When these grids are tightly bolted or riveted together the gauze is held in place rigidly. The grids or punchings, also, abstract heat from the flames.

In this type of protective device so many layers of gauze are necessary to insure good protection that the ventilation of the apparatus is greatly reduced and the pressure developed approaches the condition of a totally inclosed equipment. Protective devices of the wire gauze type should be well shrouded to keep out dust.

PLATE PROTECTION.

As has already been stated wide flanges abstract heat from flames passing through flanged joints. Plate protection does the same on a larger scale. A large number of thin plates are separated by other plates or spacers, and are rigidly riveted or bolted together. They require more space than heat abstractors of the gauze type, but they permit better ventilation. Because this type has comparatively large openings through which the pressure is relieved, the internal explosion pressure developed is correspondingly lower. This type should also be well shrouded in order to keep out dust.

GENERAL REQUIREMENTS.

The preceding types were used in the apparatus submitted for approval, however, other designs also have been used. The aim in all designs is to bring the hot flames in contact with as large an area of metal as possible.

Protective devices in order to be practical must have mechanical strength, durability, uniformity, and simplicity of parts, and protection from dust and mechanical injury.

Mechanical strength is needed to insure a permanent and definite relation of parts in spite of severe mine service or strains resulting from internal explosions.

The elements making up the device should be durable and not affected by heat or moisture.

A certain simplicity and uniformity of construction should be used in order that the devices shall have an identical assembly for all equipments, and that mistakes shall not be made in assembling or in reassembling after inspection. The flame safety lamp is a good example of this for, although not "fool proof," it is so constructed that a mistake in assembly is inexcusable.

Such devices should always be protected from the accumulation of coal dust by making the ports on the side or bottom of the apparatus instead of on the top, and the interior construction, as far as possible, should be designed to prevent the collection of coal dust. The protective devices should also be well protected from mechanical injury.

SCHEDULES ISSUED FOR TESTING EXPLOSION-PROOF EQUIPMENT.

Schedule 2, approved by the Secretary of the Interior, October 26, 1911, was the first schedule issued. This schedule stated fees that would be charged and conditions and requirements under which tests of explosion-proof motors would be made. One investigation was completed under its regulations. Schedule 2A[a], revised edition of Schedule 2, was issued November 2, 1915. The remaining investigations reported in this bulletin were made under its regulations. The full text of Schedule 2A follows:

PROCEDURE FOR ESTABLISHING A LIST OF PERMISSIBLE EXPLOSION-PROOF ELECTRIC MOTORS.

GENERAL STATEMENT.

An act of Congress (37 Stat., 681) approved February 25, 1913, contains the following provision in regard to tests performed by the Bureau of Mines:

That for tests or investigations authorized by the Secretary of the Interior under the provisions of this act, other than those performed for the Government of the United States, or State governments within the United States, a reasonable fee covering the necessary expenses shall be charged according to a schedule prepared by the Director of the Bureau of Mines and approved by the Secretary of the Interior, who shall prescribe rules and regulations under which such tests or investigations may be made. All moneys received from such sources shall be paid into the Treasury to the credit of miscellaneous receipts.

The Bureau of Mines is making tests at its Pittsburgh experiment station in the endeavor to establish a list of permissible explosion-proof electric motors for use in mines. This schedule is issued for the information and guidance of those who may desire to submit equipment for test. It supersedes Schedule 2 issued under date of January 1, 1912, and goes into effect on approval by the Secretary of the Interior.

DEFINITION OF "EXPLOSION PROOF."

The Bureau of Mines has applied the term "explosion proof" to motors constructed so as to prevent the ignition of gas surrounding the motor by any sparks, flashes, or explosions of gas or of gas and coal dust that may occur within the motor casing.

DEFINITION OF "PERMISSIBLE."

The Bureau of Mines considers any motor to be permissible when it is the same in all respects as a sample motor that has passed certain tests made by the bureau and when it is installed and used in accordance with the conditions prescribed by the bureau.

CONDITIONS UNDER WHICH MOTORS WILL BE TESTED.

The conditions under which the Bureau of Mines will examine and test explosion-proof motors to establish their permissibility are as follows:

[a] Procedure for establishing a list of permissible explosion-proof electric motors for mines, fees, character of tests, and conditions under which motors will be tested, Schedule 2A. Bureau of Mines, Nov. 21, 1915, 11 pp.

1. The tests will be made at the experiment station of the Bureau of Mines at Pittsburgh, Pa.

2. Applications for tests shall be addressed to the Director, Bureau of Mines, Washington, D. C., and shall be accompanied by a certified check or draft made payable to the Secretary of the Interior to cover the fees, and by the information specified below:

(*a*) The complete rating of the motor in accordance with the 1914 standardization rules of the American Institute of Electrical Engineers.

(*b*) Dimension drawings that show clearly—

The size and general appearance of the motor casing.

The size and details of the protective devices and their relative arrangement on the motor casing.

The relative arrangement of the parts within the motor casing.

The same information in regard to the starting rheostat and controlling appliances as is requesed for the motor.

Any other drawings necessary to identify or explain any feature that is to be considered in the approval of the motor or its accessories.

A copy of the description and a duplicate set of the drawings shall be sent to the electrical engineer, Bureau of Mines, Pittsburgh, Pa.

3. As soon as possible after the receipt of application for test the manufacturer will be notified of the date on which his motor will be tested.

4. The manufacturer is to deliver to the Bureau of Mines, Pittsburgh, Pa., one week prior to the date set for the test, the motor that he desires tested, completely prepared for test in every particular. If requested to do so, the manufacturer shall provide a man to assist in mounting the motor and connecting it for test; and the manufacturer, if he so desires, may have a representative present throughout all the tests.

5. No one is to be present at the time these tests are made except the necessary Government officers at the experiment station, their assistants, the representative of the manufacturer of the motor under test, and such other persons as may be mutually agreed upon by the manufacturer and the representatives of the bureau.

6. No tests leading to an approval will be made of any motor unless it is in the completed form in which it is to be put on the market.

7. The tests will be made in the order of the receipt of application for them, provided that the necessary equipment is submitted at the proper time.

8. The details of the results of the tests shall be regarded as confidential by all present at the tests and shall not be made public in any way prior to the formal approval of the motor by the Bureau of Mines.

REQUIREMENTS FOR APPROVAL OF MOTORS.

The qualifications that an explosion-proof equipment must have to pass successfully the inspection and tests required by the bureau are stated below:

CONSTRUCTION.

The construction of permissible explosion-proof motors and their accessories must be especially durable. This requirement will be applied consistently to all the details of the machine, as well as to its principal parts, in order that there may be assurance that, under the severe conditions imposed by mining service, the explosion-proof qualities of the equipment will remain unimpaired.

The protective devices used with permissible explosion-proof motors must not only be capable of preventing the passage of flames from the interior to the

exterior of the motor casing, but must also possess sufficient mechanical strength to insure against the accidental destruction of their prospective qualities. If there are moving parts in connection with such devices, these parts should be so designed that there can be no interference with their movement.

All leads entering explosion-proof casings should pass through the casing in the form of properly protected insulated studs of approved design. The use of rubber bushings will not be approved because the bushings may become displaced and thus destroy the explosion-proof quality of the casing.

CONTROLLING APPLIANCES.

Starting rheostats and other necessary equipment that may cause an ignition of gas must be protected as adequately as the motor itself. The casings of starting rheostats must be explosion proof. The resistances and contacts of the starting rheostats used with portable motors of not more than 50-horsepower capacity should be inclosed in the same box, unless inclosed in separate boxes connected by approved piping through which all leads are carried.

The casing of the starting rheostat should be mounted on the motor casing, if possible, and the intercommunicating openings for the passage of leads should be made large in order to prevent the rise of pressure that always attends the propagation of an explosion through a small hole from one compartment to another.

If it is not possible to mount the starting rheostat on the motor frame, all leads connecting the starter with the motor should be carried in rigid metallic conduit.

Unless means for opening the circuit both automatically and by hand are provided in a separate explosion-proof casing, they should be incorporated in the design of the starting rheostat. If the starting switch is mounted on the frame of the motor, provision should be made for entirely disconnecting the electric circuit from the starting switch.

MOTOR CASING.

All joints in the casing of a motor or of any of its accessories must be metal-to-metal joints with faces not less than 1 inch wide, and if the pressure developed in the motor casing by explosions exceeds 50 pounds per square inch the faces must be not less than 1½ inches wide. All bolt holes in casings must be bottomed or so arranged that the accidental omission of a bolt will not give an opening through the casing. All openings in the motor casing other than those provided with protective devices by the manufacturers must be tightly closed. It is desirable that such openings be as few as possible. There should be no exposed terminals or contacts outside the motor casing. If there are glass-covered openings in the casing of a motor, the glass should be of ample thickness and should be protected by strong metal covers that close automatically unless held open by hand. Armature bearings must be so designed that under no circumstances can an explosion be propagated from the interior of the motor casing around the armature shaft or through the oil wells.

CABLE REEL AND TRAILING CABLE.

If there are any sliding or rubbing contacts in connection with the cable reel, such contacts should be provided with explosion-proof protection, and any plug connections should be constructed so that they will be explosion proof. At the point where the trailing cable enters or joins the frame of portable

electric equipment, there shall be provided means for minimizing abrasion and preventing short bends from occurring in the cable. There shall also be provided an insulated clamp of approved design for securely fastening the cable and taking all mechanical strains that may be put on it.

CHARACTER OF TESTS TO WHICH MOTORS WILL BE SUBJECTED.

In testing a motor to establish its permissibility the motor casing will be filled and surrounded with the most explosive mixture of Pittsburgh natural gas and air. The motor will then be operated at its rated speed and the mixture within the casing ignited by a spark plug, by a spark from the motor brushes, or by any other means that simulates the conditions of actual practice.

Similar tests may also be made with greater and with less amounts of gas in the explosive mixture and with coal dust sifted into the motor casing or into the protective devices.

Tests will also be made to determine the point of ignition that gives the greatest pressure, and tests will be made by igniting from such a point. Not less than 50 tests of all kinds will be made, and more than that number may be made if, in the opinion of the bureau's engineers, more tests are necessary to prove the permissibility of the motor. In order that a motor shall pass these tests, it shall in none of them cause an ignition of the gas surrounding the motor or discharge flames from any part of the motor casing. Neither shall the motor develop dangerous afterburning[a] or excessive pressure in the casing of the motor or its starting rheostat.

Even after having passed the tests just described, motors or equipments will not be regarded as permissible if used under any of the conditions outlined below:

If used without the caution plate mentioned hereafter.

If used with openings in the motor casings other than those openings provided with protective devices by the manufacturer. This condition refers to all openings but especially to removable covers.

If the motor or equipment when in operation is not complete with all of the parts considered in the approval of the motor or equipment.

CAUTION AND APPROVAL PLATES.

As part of the protection of a permissible motor, the manufacturer shall be required to attach to the motor frame a metal plate inscribed as follows:

> CAUTION.
>
> The permissibility of this motor depends on the absence of any openings in the casing other than those provided with protective devices by the manufacturer.
>
> Cover plates should be screwed on tight and the casings frequently inspected for improper openings.

[a] The term "afterburning" as used in this schedule is applied to the combustion, immediately after an explosion within an explosion-proof casing, of a gaseous mixture that was not within the casing at the time of the explosion, but was drawn in subsequently while the products of the explosion were cooling.

The manufacturer shall be permitted to attach to the motor frame a plate inscribed as follows:

PERMISSIBLE EXPLOSION-PROOF MOTOR (OR EQUIPMENT).

Approval No. ——.

Issued to the————————Company.

The size, material, and design of both caution and approval plates shall meet with the approval of the bureau.

The caution and statement of approval may be combined upon a single plate, a suggested form for which is shown below:

PERMISSIBLE EXPLOSION-PROOF COAL-CUTTING EQUIPMENT.

Approval No. ——.

Issued to the————————Company.

CAUTION

The permissibility of this equipment depends on the absence of any openings in the casings other than those provided with protective devices by the manufacturer.

Cover plates should be screwed on tight and the casings frequently inspected for improper openings.

NOTIFICATION OF MANUFACTURER.

As soon as the bureau's engineers are satisfied that a motor is permissible for use in places where gas may occasionally be present in explosive proportions, the manufacturer shall be notified to that effect.

As soon as a manufacturer receives formal notification that his motor has passed the tests prescribed by the bureau, he shall be free to advertise such motor as permissible and may attach approval plates to such motors.

DRAWINGS OF APPROVED MOTORS TO BE FILED.

As the safety of an explosion-proof motor depends largely on its construction, the approval of a motor must identify the details of construction on which the approval is based. This identification will be accomplished by reference to a list of drawings and photographs that describe in detail such parts as directly or indirectly affect the safety of the motor or any of its accessories. Each list of drawings will be given a number to facilitate reference. A copy of each drawing will be filed with the Bureau of Mines.

SCOPE OF APPROVAL.

The bureau's approval of any motor shall be construed as applying to all motors of that specific type, class, form, and rating, made by the same manufacturer, that have the same construction in the details directly or indirectly affecting the safety of the motor, but to no other motors.

Manufacturers shall, before claiming the bureau's approval for any modification of an approved motor, submit to the bureau drawings that shall show the extent and nature of such modifications, in order that the bureau may decide whether test of the remodeled motor will be necessary for approval. Each approval of a permissible motor will be given a serial number.

WITHDRAWAL OF APPROVAL.

The bureau reserves the right to rescind for cause, at any time, any approval granted under the conditions herein set forth.

TESTS OF STORAGE-BATTERY LOCOMOTIVES.

Storage-battery locomotives may be submitted for test under this schedule. Their construction shall comply with the spirit of the general specifications for motors.

The motors, controllers, and resistances of storage-battery locomotives shall be explosion proof, and all interconnecting wiring shall be run in metallic conduit. The battery cells shall be installed in a locked inclosure which shall be protected in a manner consistent with the spirit of the specifications for the remainder of the equipment.

FEES FOR TESTING EXPLOSION-PROOF MOTORS, COAL-CUTTING EQUIPMENTS, AND LOCOMOTIVES.

The following fees to be charged on and after the date of approval of this schedule have been established and approved by the Secretary of the Interior:

ITEM 1. COMPLETE TESTS.

For an official investigation consisting of 50 tests of an explosion-proof motor or coal-cutting equipment, to determine its permissibility for use in gaseous mines---------- $175

ITEM 2. EXTRA TESTS INVOLVING NO PREPARATION.

It is estimated that 50 tests should be sufficient to determine the permissibility of the average motor or equipment offered, but the design may be such as to require more than this number of tests to determine the point at issue. For additional tests that involve no special preparation (for each 5 tests or fraction thereof) 5

ITEM 3. SPECIAL TESTS INVOLVING PREPARATION OF EQUIPMENT.

Special tests involving preparation of equipment during the course of the investigation will be made at the request of the manufacturer and will be charged for in accordance with the work involved. A deposit of $100 will be required to cover special tests, but the entire amount will be refunded if no special tests are made.

ITEM 4. TESTS OF STORAGE-BATTERY LOCOMOTIVES.

The expense of testing storage-battery locomotives in the present state of the art can not be determined exactly and such tests will be charged for in accordance with the work involved. A deposit of $200 will be required for such locomotive tests. If the expense of testing is less than $200, the balance will be refunded.

The fees specified above may be increased to cover the cost of testing an unusually complicated type of equipment, and are also subject to change on the recommendation of the Director of the Bureau of Mines and the approval of the Secretary of the Interior.

SYNOPSIS OF PROCEDURE TO BE FOLLOWED IN MAKING APPLICATION FOR TESTS, SUBMITTING MATERIAL, CONDUCTING TESTS, AND NOTIFYING APPLICANT OF RESULTS.

1. Application for tests should be addressed to the Director of the Bureau of Mines, Washington, D. C. This application should be accompanied by check or draft made payable to the Secretary of the Interior, and by a complete rating of the motors to be tested, and a set of the drawings described under the foregoing heading, "Drawings of Approved Motors to be Filed." Duplicate copies of the application and drawings should be sent to the electrical engineer, Bureau of Mines, Pittsburgh, Pa.

2. As soon as the application has been reviewed by the bureau's engineers the applicant will be notified of the date of tests.

3. After the applicant has received this notification, he should send the material required to the electrical engineer, Bureau of Mines, Pittsburgh, Pa. The material should be delivered not less than one week in advance of the date set for the beginning of the tests.

4. The tests will be begun on the date set and continued until the motor has been approved, rejected, or withdrawn.

5. After the bureau's engineers have considered the results of the tests, a formal report of the approval or disapproval of the motor will be made to the applicant in writing by the Director of the Bureau of Mines. No verbal report will be made, and the details of the tests must be regarded as confidential by all present.

VAN. H. MANNING,
Director.

Approved Nov. 2, 1915.
BO SWEENY,
Assistant Secretary.

GAS AND EQUIPMENT USED.

GAS.

Natural gas composed[a] approximately of 82 per cent methane, 16.4 per cent ethane, 1.5 per cent nitrogen, and a trace of carbon dioxide was used in all tests. The term "gas" used in describing tests refers to this natural gas.

The most explosive mixture[b] of such gas and air is in the proportion of 8.6 to 91.4. Such a mixture also burns most rapidly and gives off the greatest amount of heat.

TESTING EQUIPMENT.

This investigation was conducted chiefly with apparatus described in detail in the report of the preliminary investigation.[c] As the principles governing the tests were the same for both the old and new equipments, the old equipment will not again be described. The bureau, jointly with the Jeffrey Manufacturing Co., designed a new testing outfit, which was built and installed as a gift to the bureau by the manufacturers of explosion-proof apparatus.

The complete testing gallery consists of the following parts: 1, An explosion chamber in which tests are made; 2, a fan and piping system for mixing and circulating the explosive mixture in the explosion chamber and in the equipment under test; 3, a switchboard on which is mounted the electrical controlling apparatus and wiring for directing the action of the gallery; 4, a crane surmounting the gallery equipped with a 3-ton electric hoist; 5, other miscellaneous apparatus, including a gas meter for measuring the gas admitted, a pressure indicator that can be attached to the casing of the apparatus to record the pressure developed therein by the explosion, and spark plugs that can be mounted in the apparatus to initiate explosions at desired points.

EXPLOSION CHAMBER.

The explosion chamber consists of a cylindrical steel tank with an internal diameter of 10 feet and a height of 4½ feet. The cylinder sits in the recess of an iron channel ring embedded in a concrete base. The joint between the bottom of the cylinder and the channel iron is made gas-tight by a water seal.

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[a] Hall, Clarence, Snelling, W. O., and Howell, S. P., Investigations of explosives used in coal mines, with a chapter on the natural gas used at Pittsburgh, by G. A. Burrell, and an introduction by C. E. Munroe, Bull. 15, Bureau of Mines, 1912, p. 66.

[b] Hall, Clarence, Snelling, W. O., and Howell, S. P., Work cited, p. 77.

[c] Clark, H. H., Investigation of explosion-proof motors, Bull. 46, Bureau of Mines, 1912, 44 pp.

Plate I, *A* shows the chamber closed and the operator at one observation window about to witness a test; at his right is the firing switch to which are connected flexible leads, *a*; *b* is the ignition line from the spark coil. There are four of these observation windows equally spaced around the cylinder. Plate I, *B* shows a closer view of these windows and the shrouded hood for protecting the operator from flames issuing from the top of the chamber. Canvas curtains that fit over the hoods may be used to darken the interior and to enable the observer to see better the results of the explosion. In this view the cover or top of the chamber is shown raised in position for airing out the chamber and also to permit the operator to enter and to make necessary connections, changes, or inspection. When the gas within the inclosure is exploded the pressure is released through the oiled-paper heads *a*, Plate I, *B*. These heads are held in position by iron rings, *b*, with rounded edges that fit closely in grooves. When the gallery is not in use the heads are protected from the weather by sheet-iron covers. The rim *c* of the top sits in the channel *d*, when the chamber is closed for test, and a gas-tight joint is obtained by filling the channel with either grease or water.

FAN AND CIRCULATING SYSTEM.

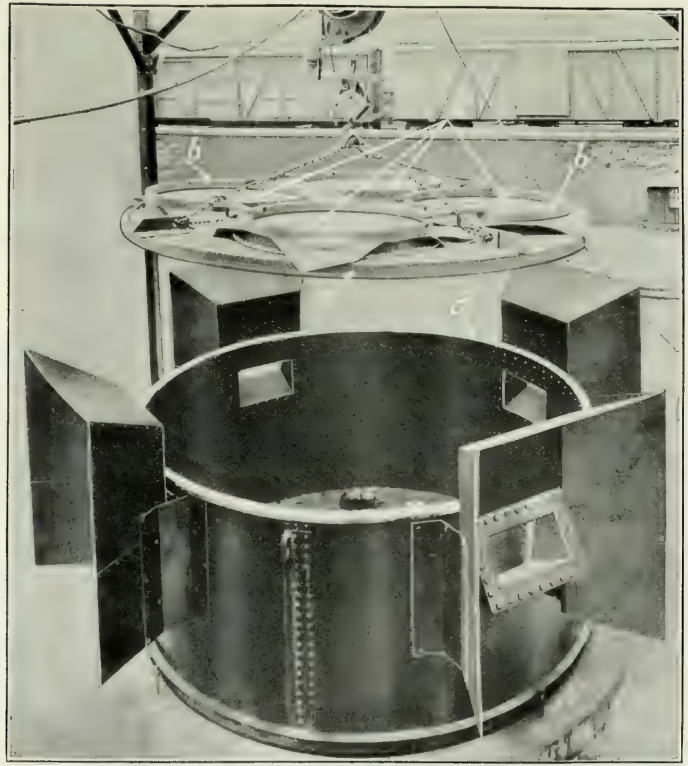
Figure 1, a diagram of the testing apparatus, shows clearly the arrangement of piping, valves, etc., of the circulating system, also shown in part in Plate II, *A*. By means of this apparatus a uniform mixture of gas and air may be obtained in the chamber as well as in the motor or other apparatus under test. The mixture is discharged into the bottom of the chamber at two diametrically opposite points. These discharge points or outlets are about six inches from the cylindrical wall and are so formed as to give the mixture a rotary motion, thus effectively mixing the gallery atmosphere with the entering gas. The main suction line from the fan enters the chamber floor near its center. By proper manipulation of valves an auxiliary suction line is used when filling the machine to be tested with the explosive mixture.

SWITCHBOARD.

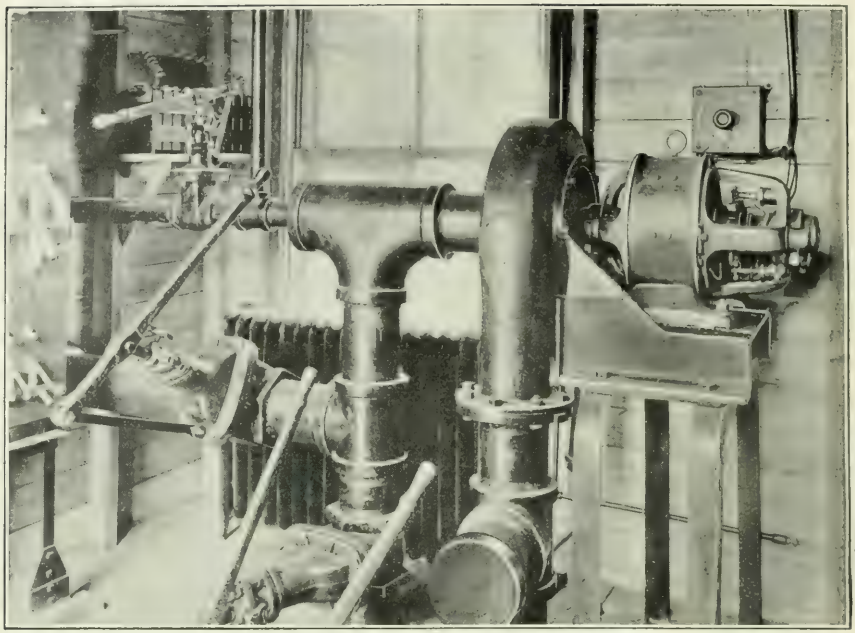
On the switchboard shown in Plate II, *B* are mounted the controller *a*, for operating the crane-hoist motor, and the switch mechanism *b* that times the ignition with the release of the indicator drum and the switch for operating the circulating fan and other circuits connected with the testing gallery.

Below the switchboard are shown the chains *c* that are used to open and close valves in the piping connections of the apparatus under test, thus permitting the operator to fill one or more compartments of the apparatus with the gaseous mixture.

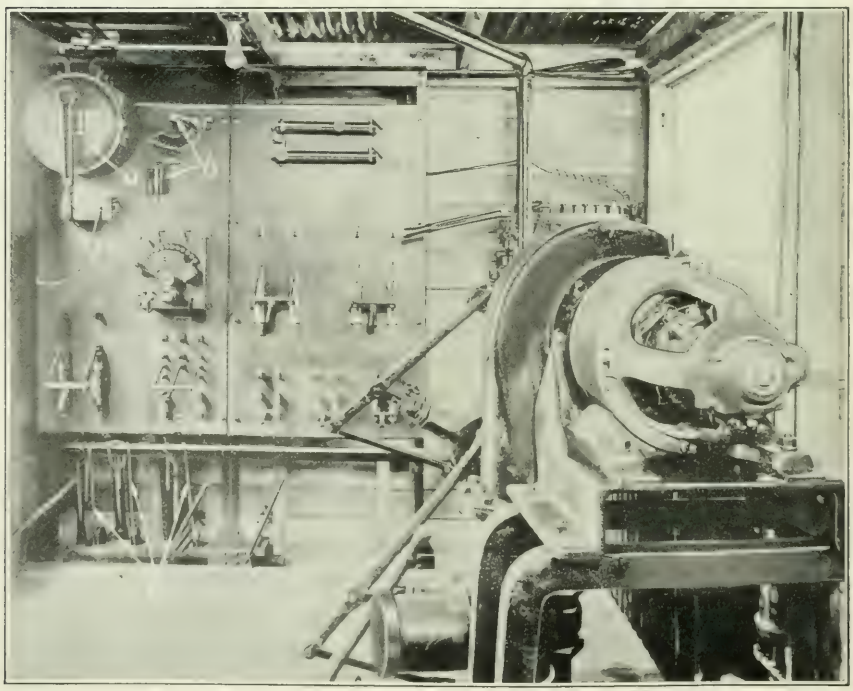
A. EXPLOSION-PROOF MOTOR-TESTING GALLERY; CHAMBER CLOSED AND OPERATOR IN POSITION FOR OBSERVING RESULTS OF TESTS.



B. EXPLOSION-PROOF MOTOR-TESTING GALLERY; CHAMBER OPEN FOR AIRING OUT AND TO PERMIT OPERATOR TO ENTER.



A. CIRCULATING FAN, WITH MOTOR AND PARTS OF PIPING SYSTEM.



B. SWITCHBOARD AND CONTROL APPLIANCES.

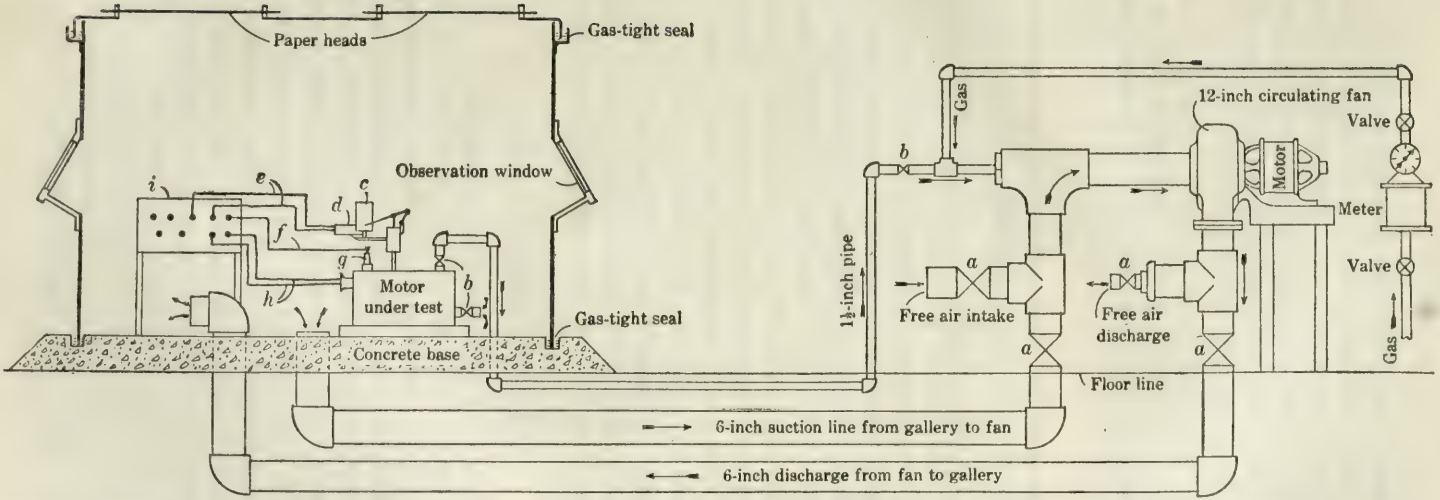


FIGURE 1.—Elevation of testing apparatus. *a*, Control valves, gallery circulating system; *b*, control valves, motor circulating system; *c*, recording pressure indicator; *d*, release magnet for pressure indicator; *e*, connections for switchboard to release magnet; *f*, ignition line; *g*, spark plug; *h*, power lines to motor; *i*, terminal board.

CRANE.

Plate I, A, shows the gallery superstructure and the hoist used in connection with the testing gallery. The 3-ton hoist *c* raises and lowers the cover, or transfers apparatus in or out of the chamber, and when necessary lifts the cylinder from the concrete base. The ropes *e* are attached to the hoist and are used to pull it in either direction along the I-beam *d*.

After each test the cover is raised to air out the chamber and to permit the operator to enter it. As the entire top of the chamber can be lifted, the gas can be removed quickly and there is little delay between tests.

APPLICATION OF SCHEDULE 2A TO THE TESTING OF COMMERCIAL EQUIPMENT.

ASSISTANCE RENDERED BY THE MANUFACTURER.

The manufacturer who submits equipment for test is required to furnish one man familiar with the equipment to assist with the investigation. This man may or may not represent the manufacturer as a witness at the tests. His chief service to the bureau is to assist in setting up the equipment for test and in making any changes necessary in the progress of the investigation. The manufacturer is expected to prepare the equipment for test in so far as concerns drilling holes and tapping holes for the circulating pipes, pressure gage, and spark-plug connections. This work is laid out by the bureau's engineers and then done either at the bureau's machine shop or at some nearby plant by the company submitting the apparatus.

FACTORS CAUSING DELAY.

In the bureau's tests of commercial equipment there are several causes of delay that have considerably increased the expense to the several submitters. By noting the following deficiencies future applicants may avoid similar troubles. Almost all equipments submitted have had holes through the casing walls instead of bottomed holes or some other means of preventing an accidental opening by the omission of a bolt, although this is contrary to the schedule requirement. In many equipments the flange making up the flange joint is not effective either because of higher internal pressures than were expected or of insufficient contact of the metal at certain points where the castings do not align properly or where material is insufficient. Excessive pressure in the final compartment of the series, caused by the propagation of explosions from one compartment to another, has made changes in design necessary and has seriously delayed the tests.

DRAWINGS.

In those investigations connected with small apparatus, such as flame or electric lamps, the bureau retains a sample of the lamp tested as a permanent record, so that a comparison can be made at any future time to determine whether the manufactured product has changed. For coal-cutting equipment this practice evidently is not feasible. In order, however, that the bureau shall have a concise record of the equipment tested, very complete drawings showing the details of construction, materials used, and in every way identifying the equipment approved are required. These drawings together with photographs of the equipment make up a "drawing list" kept on permanent file with the bureau.

That modifications of the design will be necessary from time to time is recognized, and the schedule takes care of such contingencies by requiring the manufacturer to submit drawings that show the extent and nature of such changes, in order that the bureau may decide whether or not further tests are necessary.

As the approval covers only apparatus built in accordance with the drawing list, which is revised to take in all authorized extensions of approval, any modifications made in the construction of approved apparatus without the bureau's knowledge renders the approval void.

In applying any schedule to the testing of commercial equipment, points will come up that are not entirely covered by the schedule. An endeavor is made to handle such points to the satisfaction of the parties interested. The intent of a schedule is to direct investigations and give fundamental rules for testing and approving equipment. The details for individual cases should be worked out with the object of the approval system in mind, namely, the development of equipment that will safeguard the life of the miner.

INSPECTION AND MAINTENANCE OF APPROVED EQUIPMENT.

The bureau's tests cover only the examination and test of one equipment. Neither funds nor men are available for establishing systematic factory inspection of approved equipment. Therefore, the reliability of approved equipment must rest to a considerable extent with the manufacturer, who is responsible for placing the permissible stamp on each individual equipment. Some manufacturers, recognizing this responsibility, have established special regulations that require a rigid certified inspection of each approved equipment at the factory. Such regulations promote safety and hence are highly commendable.

The bureau's approval is based on satisfactory operation under service conditions. As a result of field investigations additional modifications have been recommended, and these recommendations

were promptly taken under consideration and acted on by manufacturers. Such a spirit of cooperation between the bureau and the manufacturer to make approval apparatus safer can not but favorably impress the mine operator and the miner.

Not only is the manufacturer expected to do his part, but the purchaser of approved equipment should have an equal interest in its proper maintenance. Both the user and the manufacturer have claimed occasionally that such apparatus would not be kept clean or would not be properly assembled after inspection. Such statements show a wrong attitude toward safety equipment. The miners' safety lamp is cleaned and carefully assembled by a trusted employee. The safety catches on a shaft cage are kept in working order. If this is true, then the employee who has the maintenance of approved coal-cutting equipment could be so trained that he will see in it a safety apparatus, one in which to take pride, to inspect, to assemble properly, and to keep at all times in a safe condition. The operator should share with the bureau and the manufacturer the responsibility for continuing the safety of approved equipment.

EQUIPMENTS APPROVED AND DESCRIPTION OF TESTS.

APPROVALS GRANTED UNDER SCHEDULES 2 AND 2A.

The coal-cutting equipments and accessories which have been tested and approved under schedules 2 and 2A are as follows:

APPROVED EQUIMENTS.

Approval No. 100, Sullivan CE–7 d. c. machine with 250-volt motor.
Approval No. 100A, Sullivan CE–7 d. c. machine with 500-volt motor.
Approval No. 101, Goodman 23–C d. c. machine with 250-volt motor.
Approval No. 101A, Goodman 23–C d. c. machine with 500-volt motor.
Approval No. 102, Jeffrey 28A d. c. machine with 250-volt motor.
Approval No. 102A, Jeffrey 28A d. c. machine with 500-volt motor.
Approval No. 103, Jeffrey 35B d. c. machine with 250-volt motor.
Approval No. 103A, Jeffrey 35B d. c. machine with 500-volt motor.
Approval No. 104, Sullivan CE–7 a. c. machine with 220-volt motor.
Approval No. 104A, Sullivan CE–7 a. c. machine with 440-volt motor.

TEST PROCEDURE.

All apparatus submitted for approval under schedule 2A is first given a preliminary inspection to detect faults of design or construction not consistent with the schedule of requirements. After this the apparatus is tested in gas for safety from ignition of fire damp. The cycle of operation made for a given test is as follows:

1. The equipment is placed in the testing gallery and is piped to the gas-circulating system so that any or all compartments can be filled with a mixture of gas and air.

2. Arrangements are made for the installation of spark plugs at different points in order that the point of ignition shall be under the operator's control.

3. Provision is also made to connect a pressure indicator at different points in order to obtain a record of the pressure developed by the explosion in the compartment under observation.

4. In tests to determine the effect of the presence of coal dust in the atmosphere, the dust is sifted into the openings or into the compartments proper.

5. When the spark plug and pressure indicator have been connected at the desired points, the testing gallery is closed, and an explosive mixture of gas and air is made by adding the proper quantity of gas and thoroughly mixing it with the air.

6. The explosive mixture is then drawn into the compartment or compartments under test.

7. Observers are stationed at the observation windows of the gallery.

8. The mixture within the compartment is ignited by means of the spark plug, and this ignition is automatically timed with the release of the indicator drum to give a satisfactory pressure diagram.

9. Observations are recorded.

10. The gallery is opened and the gas mixture removed by the circulating system.

11. The operator enters the gallery, makes his inspection, removes the indicator card and prepares the motor for the next test.

The percentages of gas generally used in the tests are 8.6 and 7.0, both with and without coal dust.

During these tests the gas mixture surrounding the apparatus must not ignite, flames must not pass through the flange joints, bearings or protective devices, and prolonged afterburning or excessive pressure must not develop in any of the compartments.

SULLIVAN DIRECT-CURRENT COAL-CUTTING EQUIPMENTS, APPROVALS NO. 100 AND 100A.

The Sullivan Machinery Co. of Claremont, N. H., made application under Schedule 2 for the test and approval of a 250-volt equipment and submitted a machine equipped with a 250-volt motor for inspection and test. Later a request was made for the approval of a 500-volt equipment. The company was not required to submit a complete 500-volt unit, but only 500-volt fuses and cable-reel disconnecting plugs, as the mechanical construction for the two voltages was so nearly identical that the investigation of the 250-volt equipment could be held to apply to the higher voltage machine in all other respects.

DESCRIPTION OF CE-7 DIRECT-CURRENT EQUIPMENTS.

The equipments covered by this investigation are designated as Type CE-7 continuous-cutting chain machines designed for room-and-pillar work. Approval No. 100 was assigned to the 250-volt d. c. equipment and 100A to the 500-volt unit of the same type.

The electrical parts considered in granting the approvals were the motor, the rheostat, the controller and fuse, the cable reel, and the wiring. Plate III, *A*, shows the assembled machine and Plate V, *A*, shows the assembled cable reel.

Drawing lists 100 and 100A, kept on file with the bureau, give the essential details of construction upon which approvals 100 and 100A, respectively, were based.

MOTOR.

The motor used with these equipments is a direct-current, multipolar, compound-wound machine designed to deliver 30 horsepower for one hour without exceeding a temperature rise of 75° C. Access to the brush holders and commutator is provided by a flanged cover directly over them.

CONTROLLER AND STARTING RHEOSTAT.

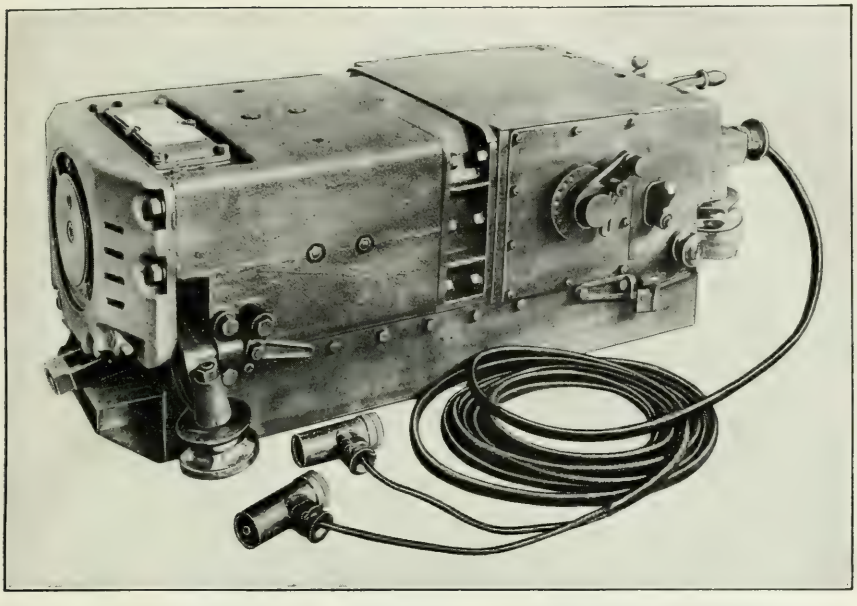
Plate III, *B*, shows the back of the controller *a* removed from the compartment *b*. This controller is fastened to the flanged cover *c*, which is securely bolted to the main casting by means of the studs *d*. The fuse plug *e* is inserted in the cover *c* and is so interlocked with the controller that the controller handle must be in the extreme "off" position before a fuse can be removed or replaced. The controller is equipped with magnetic blow-out coils.

The bell-mouthed bushing *f* serves as the entrance of the cable to the machine.

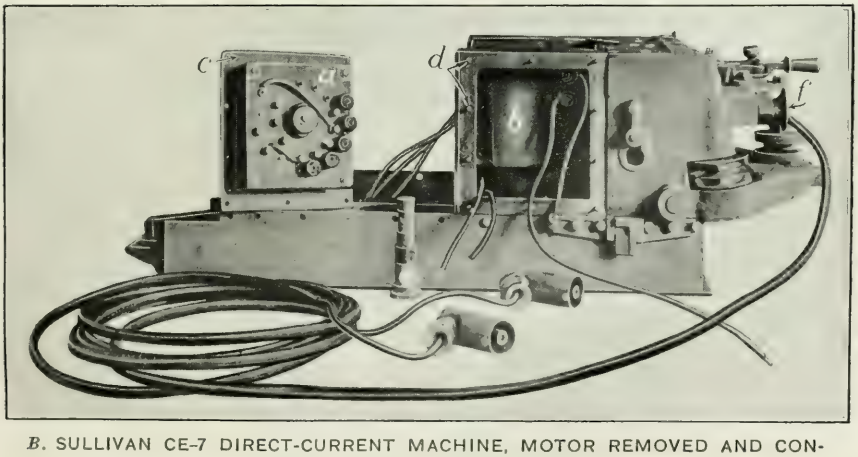
Plate IV shows the machine in a reversed position, with the rheostat cover removed. As the rheostat *a* is installed within the main casting it is well protected from mechanical injury. The cables *b* connect with the motor through the passage *c* in the rear head.

CABLE REEL.

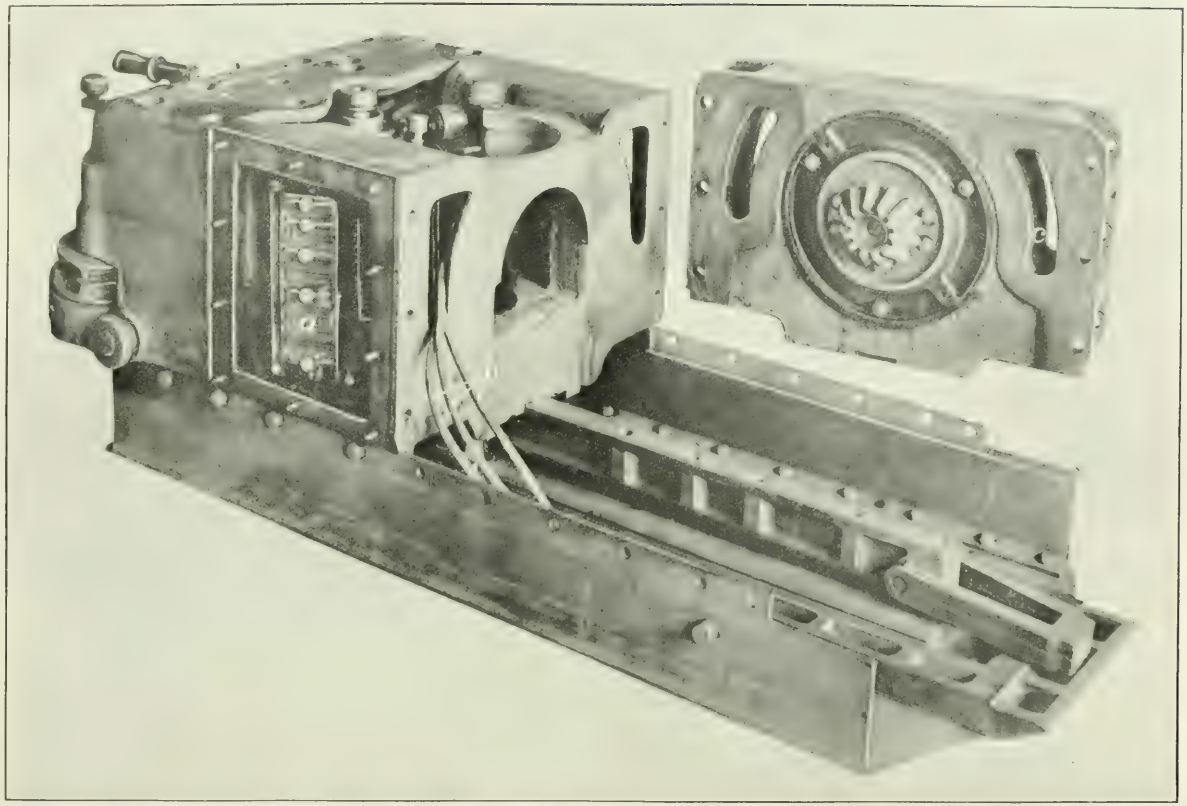
The cable reel is mounted on an extension of the power car or truck that is used for transferring the machine proper from place to place. In Plate V, *A*, are shown the cable reel and disconnecting plugs by means of which connection is made between the machine and cable reel. One of these plugs is shown in service position in Plate V, *B*, the other is seen partly dismantled. A brass sleeve, *a*, contains a magnetic blow-out coil, which prevents an arc from being drawn into the atmosphere when contact is broken between the brass sleeve



A. SULLIVAN CE-7 DIRECT-CURRENT MACHINE.



B. SULLIVAN CE-7 DIRECT-CURRENT MACHINE, MOTOR REMOVED AND CONTROLLER OPEN FOR INSPECTION.



SULLIVAN CE-7 DIRECT-CURRENT MACHINE, REAR HEAD REMOVED TO THE RIGHT AND RHEOSTAT COMPARTMENT OPEN FOR INSPECTION.

and the connection within the extension *b* on the slip-ring housing *c*. The blow-out coil is mounted within the shrouding cylinder *d*, which has a bell-mouthed cable entrance, *e*.

SAFETY FEATURES.

Plate VI, *A*, shows the commutator end or front head with one element of the double protective device removed from the head. Plate VI, *B*, shows a similar view of the gear end or rear head. Each element is made up of 35 sheet steel punchings or plates 0.0187 inch thick, which are separated by spacers of the same thickness. The general construction of the plate type of protective device can be seen by reference to Plate VI, *A*. The plates *a* are riveted between the rings *b*. The openings *c* project downward as shown in figure 2 and prevent excessive clogging by coal dust. Figure 2 also shows the paths that the burned gases must traverse when discharged through the protective devices to the atmosphere.

All joints between compartments or between covers and compartments have wide flanges secured by studs or bolts with bottomed holes which preclude the possibility of a hole through the explosion-proof casing due to the accidental omission of a bolt.

The fuse in the controller compartment is so arranged that it can not be removed or replaced under load. The cable-reel disconnecting plug was developed as the result of experience with several unsatisfactory designs. In its final form it proved, under extremely severe tests, to be explosion-proof when the circuit was opened under load.

The wiring between the motor, the controller, and the rheostat compartments is well protected as it is run within the machine. The trailing cable is protected by bell-mouthed bushings where it enters the main frame and the cable-reel plugs.

INVESTIGATION OF 250-VOLT EQUIPMENT.

A 250-volt equipment, comprising a motor, controller, rheostat, and cable reel, was submitted for investigation.

PRELIMINARY INSPECTION AND RECOMMENDATIONS.

The preliminary inspection of the Sullivan d. c. equipment revealed a number of unsatisfactory features.

Recommendations were made for changes in design of the fuse box, the entrance of trailing cable to the machine, the method of securing the starting-box cover, and the cable-reel parts.

NATURE OF TESTS.

The motor was tested in 8.6 per cent gas and in 7 per cent gas, both with and without coal dust. Most of the tests were made with

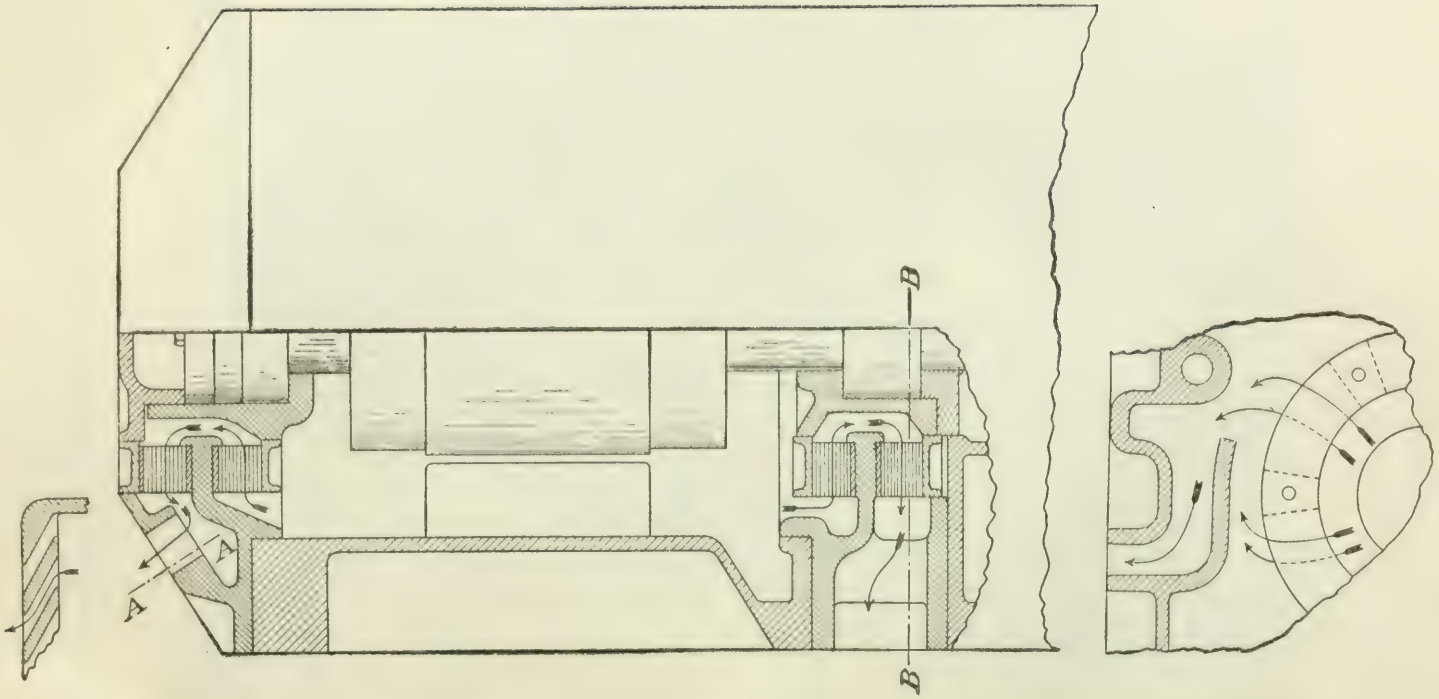
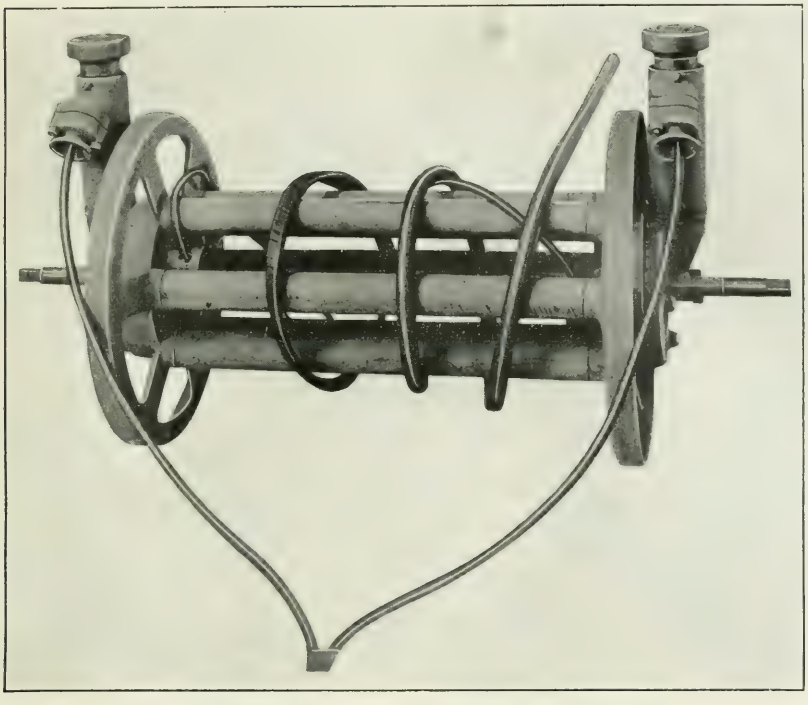
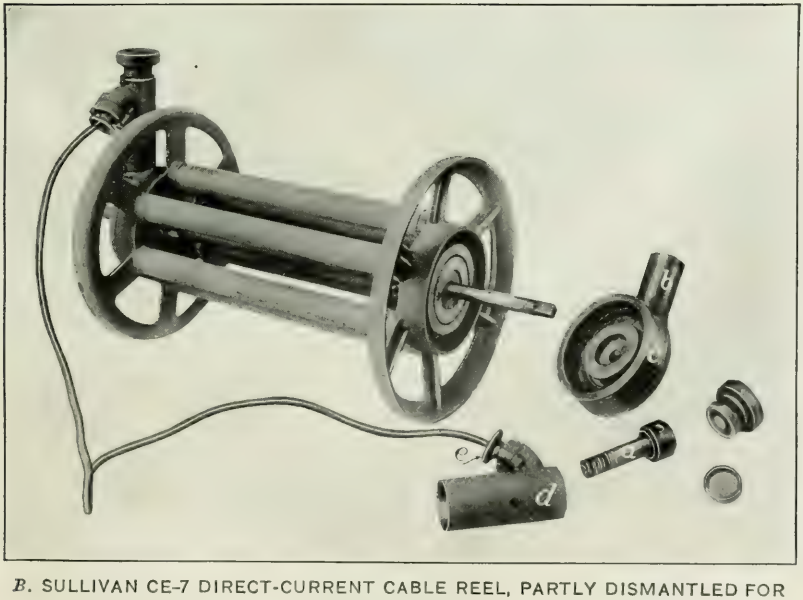


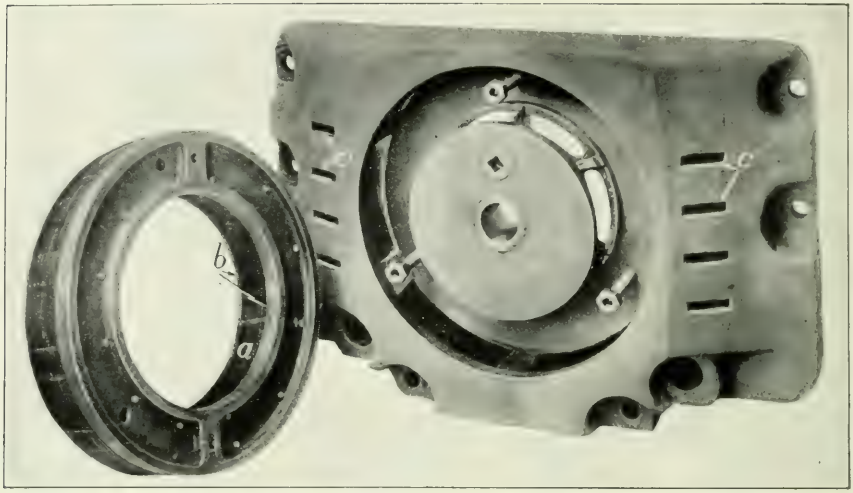
FIGURE 2.—Paths of burned gases discharged through protective devices of Sullivan CE-7 explosion-proof motors. At left is shown section through *AA*; and at right, section through *BB*.



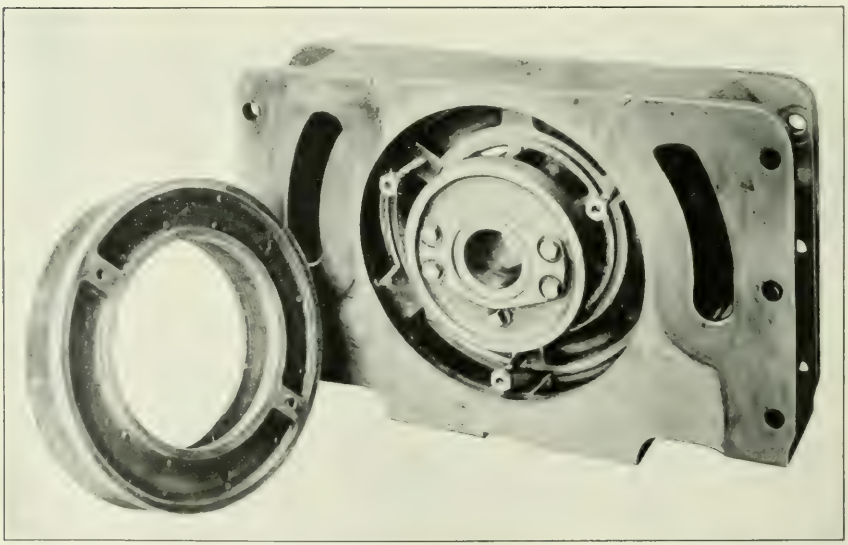
A. SULLIVAN CE-7 DIRECT-CURRENT CABLE REEL.



B. SULLIVAN CE-7 DIRECT-CURRENT CABLE REEL, PARTLY DISMANTLED FOR INSPECTION.



A. SULLIVAN CE-7 DIRECRT-CURRENT MACHINE, FRONT HEAD WITH ONE ELEMENT OF PROTECTIVE DEVICE REMOVED.



B. SULLIVAN CE-7 DIRECT-CURRENT MACHINE, REAR HEAD WITH ONE ELEMENT OF PROTECTIVE DEVICE REMOVED.

the motor running. The effect of raising the covers of the explosion-proof compartments $\frac{1}{32}$ inch was also tried.

Tests were made to show the explosion-proof qualities of the casings that protect the slip-ring contacts in the cable reel. These tests were made in 8.6 and 7 per cent gas, with and without coal dust.

The cable-reel disconnecting plug, by which connection between the machine and cable reel is made, was tested both in 8.6 per cent gas and in air for explosion-proof qualities. Tests of this plug were also made to determine whether the casing of the plug would become charged and cause an electric shock.

The 250-volt fuse was tested in air by throwing it directly across a 250-volt, 200-kw., d. c. generator, in series with a small resistance approximately equivalent to a double circuit of No. 4/0 wire 530 feet long.

EXPLOSION PRESSURES OBTAINED.

The maximum indicated pressures for the machine as first received were as follows:

In the motor compartment_____ _____7.0 pounds per square inch
In the controller compartment_____126.0 pounds per square inch
In the slip-ring compartment of the cable-reel.
35.0 pounds per square inch

With the design of machine as finally approved, the average maximum pressures were:

In the motor compartment_____42.0 pounds per square inch
In the controller compartment_____40.6 pounds per square inch

There was no change made in the design of the slip-ring compartment of the cable-reel, therefore the maximum pressure remains the same as above.

CHANGES IN DESIGN.

As a result of tests and inspection at the testing station, the machine as first approved included changes in design as follows:

1. A refillable fuse, explosion-proof and interlocked with the controller, replaced the fuse in a separate oil-filled box.
2. Unbottomed bolt holes were eliminated.
3. Specially designed, insulated studs replaced soft rubber bushings that were submitted for the protection of cables where they entered explosion-proof casings.
4. Insulated strain clamps were used.
5. The communicating passage between the motor and starting-box was enlarged.

Experience with approved machines in service brought about the following additional changes in design:

1. A bell-mouthed bushing replaced the flexible metallic tubing submitted for the protection of the trailing cable from abrasion where it entered the machine and the cable reel.

2. The openings at the top of the machine for the discharge from the protective devices became packed with dust. The manufacturer redesigned the machine so that the discharge was downward and at the side of the machine, thereby overcoming this defect.

3. The cable-reel disconnecting plugs were found to be inadequate in service, and after successive trials a design was evolved that proved satisfactory under severe tests.

The above changes were recommended by the bureau and were promptly made by the Sullivan Machinery Co. The approvals of the d. c. machines were extended to cover these different modifications. Plates III, *A* and *B*, IV, V, *A* and *B*, and VI, *A* and *B*, show assembled and detailed views of the latest design of equipments in which are incorporated all of the improvements just mentioned.

INVESTIGATION OF THE 500-VOLT EQUIPMENT.

From a careful study of the machine construction it was determined that a repetition of tests already made with the motor, controller, and rheostat of the 250-volt equipment was unnecessary with the same parts of a 500-volt equipment. Separate tests, however, were made of the cable-reel disconnecting plugs and fuses designed for 500-volt service.

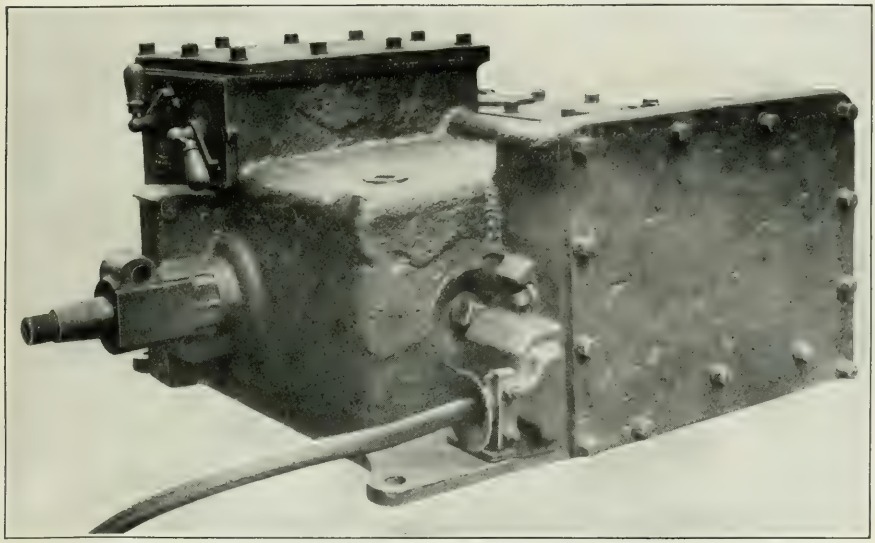
In the main the approval of the 500-volt unit was based upon the tests of the 250-volt equipment. All improvements and modifications made as the result of the laboratory and field investigations of the 250-volt equipment have been incorporated in the 500-volt machine.

SUMMARY.

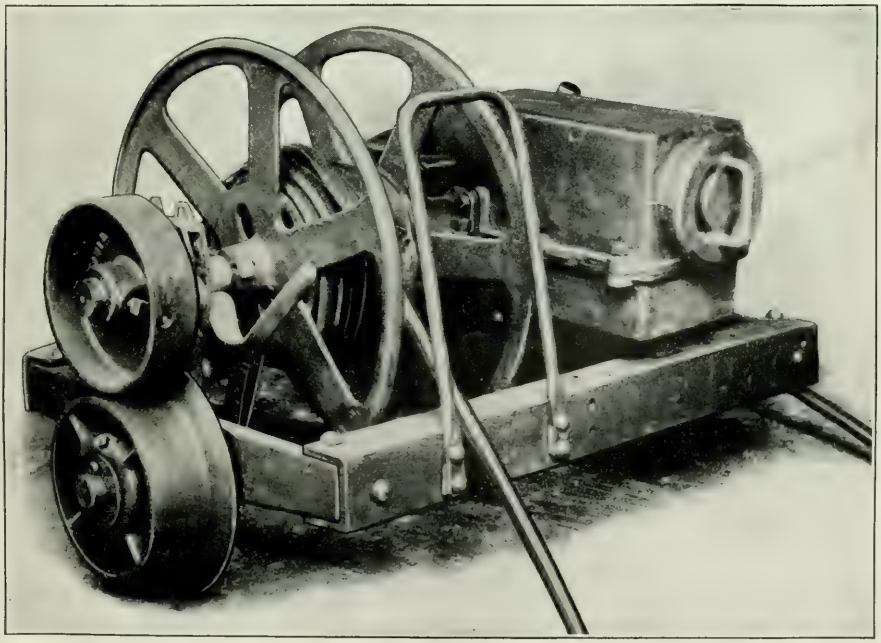
Approval No. 100, granted September 30, 1914, and approval No. 100A, granted October 20, 1914, were extended to cover changes in the cable entrance to the machine and a modification of protective devices on October 5, 1915, and to cover improvements in the cable-reel disconnecting plugs on March 10, 1916. When constructed in conformity with the machine tested and approved, the CE–7 d. c. equipments are considered safe units and are recommended for use in gaseous mines.

GOODMAN DIRECT-CURRENT COAL-CUTTING EQUIPMENTS, APPROVALS NO. 101 AND 101A.

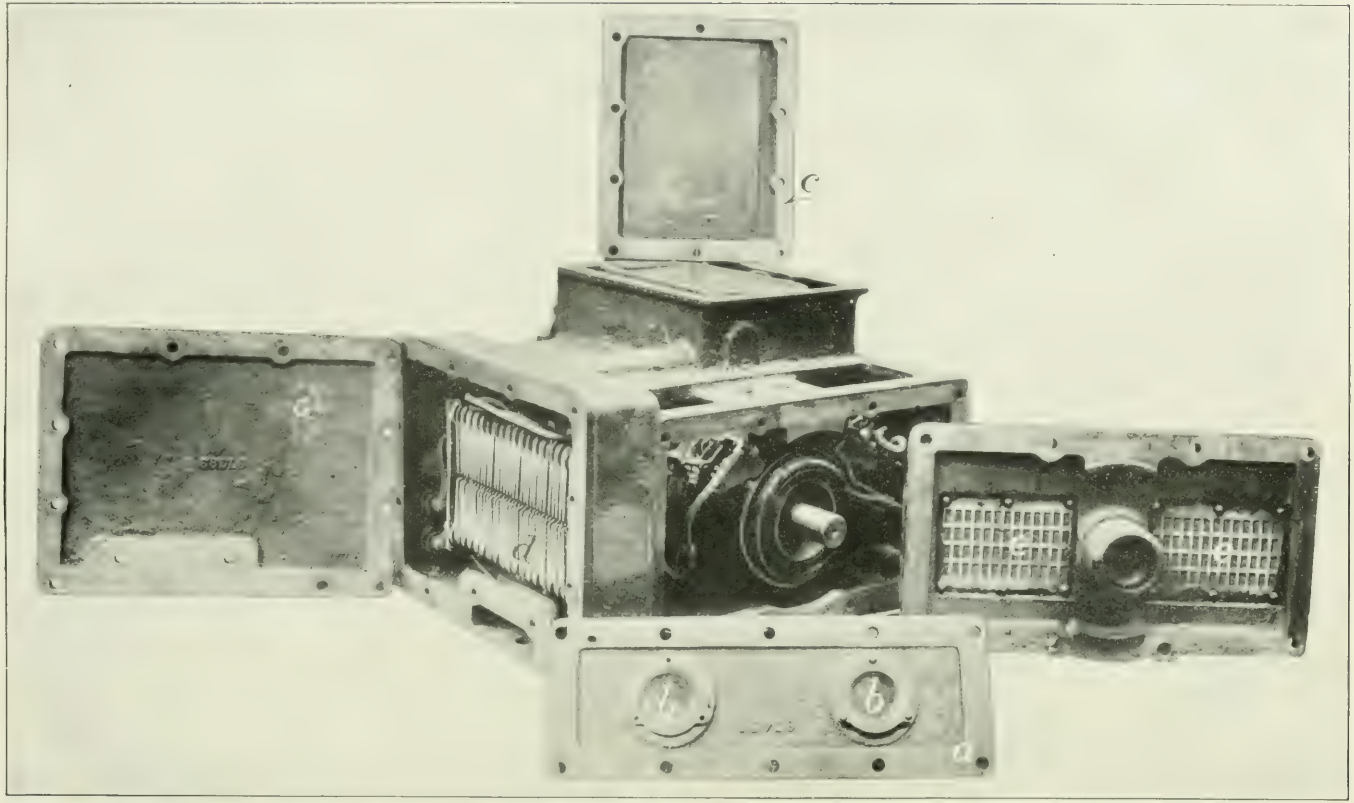
The Goodman Manufacturing Co., of Chicago, Ill., made application under Schedule 2 for the test and approval of a 210-volt equipment and submitted a 210-volt outfit for inspection and test.



A. GOODMAN 23-C DIRECT-CURRENT MACHINE.



B. GOODMAN 23-C DIRECT-CURRENT CABLE REEL AND TRUCK.



GOODMAN 23-C DIRECT-CURRENT MACHINE, OPEN FOR INSPECTION OF RHEOSTAT, CONTROLLER, ARMATURE, AND PROTECTIVE DEVICES.

When this investigation was well under way request was made for the aproval of a 500-volt unit of the same type. The company was not required to submit a complete 500-volt outfit but only a 500-volt rheostat.

DESCRIPTION OF 23–C DIRECT CURRENT EQUIPMENT.

The equipments covered by this investigation are designated as Type 23–C short-wall mining machines. Approval No. 101 was assigned to the 210-volt unit and approval No. 101A to the 500-volt unit.

The electrical parts considered in granting the approvals were the motor, the controller, the rheostat, the cable-reel and truck, including fuse and switch, and the wiring. Plate VII, *A*, gives an assembled view of the machine and Plate VII, *B*, a similar view of the cable-reel and its truck. Drawing lists 101 and 101A, kept on file by the bureau, give the essential details of construction upon which approvals 101 and 101A, respectively, were based.

MOTOR.

The motor, Plate VIII, is a direct-current, multipolar, compound-wound machine, designed to deliver 35 horsepower for one hour without exceeding a rise of temperature of 75° C. on the windings or 100° C. on the commutator. The flanged cover *a* that fits over the commutator pit has two observation windows, *b*, protected with covers kept closed by springs.

CONTROLLER AND STARTING RHEOSTAT.

Plate VIII also shows the general location of the controller compartment. This compartment is closed with a flanged cover, *c*, shown removed. The same plate presents a view of the rheostat compartment with the cover removed and a 210-volt rheostat, *d*, installed.

CABLE REEL AND TRUCK WITH FUSE AND SWITCH.

Plate VII, *B*, shows a two-wheeled truck upon which are mounted the cable reel and an explosion-proof compartment containing a fuse and a switch.

FUSE AND SWITCH.

Plate IX shows details of the explosion-proof compartment, which contains a fuse, a two-pole switch and connections to the cable reel. The fuse *a* is mounted in a holder which fits into the end of the cover, *b*, of the explosion-proof compartment. The design is such that the fuse must first be disconnected from the circuit before it can be removed from the explosion-proof compartment. When assembled

the circuit is closed through the fuse by turning the holder until the blades, *d*, engage with the clips, *e*.

The casting, *f*, serves both as a protecting cover for insulated studs which complete the circuit through the casing of the compartment, and also as the bell-mouthed bushing for the cable where it connects with the insulated studs.

The switch is in the lower part of the compartment and is operated by the handle, *c*.

SAFETY FEATURES.

The 23-C machine is provided with the gauze and grid type of protective device. The machine itself has two protective elements (Pl. VIII, *c*) installed in the end plate of the motor compartment. Figure 3 is a diagram of the path the burned gases must traverse when discharged from this compartment. The outlet from the protective devices is on the under side of the casting where it can not easily become clogged with dust.

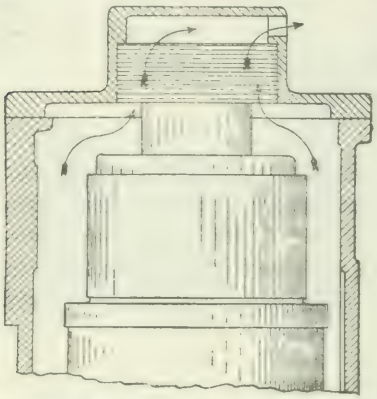


FIGURE 3.—Path of burned gases discharged through protective devices of Goodman 23-C explosion-proof motor.

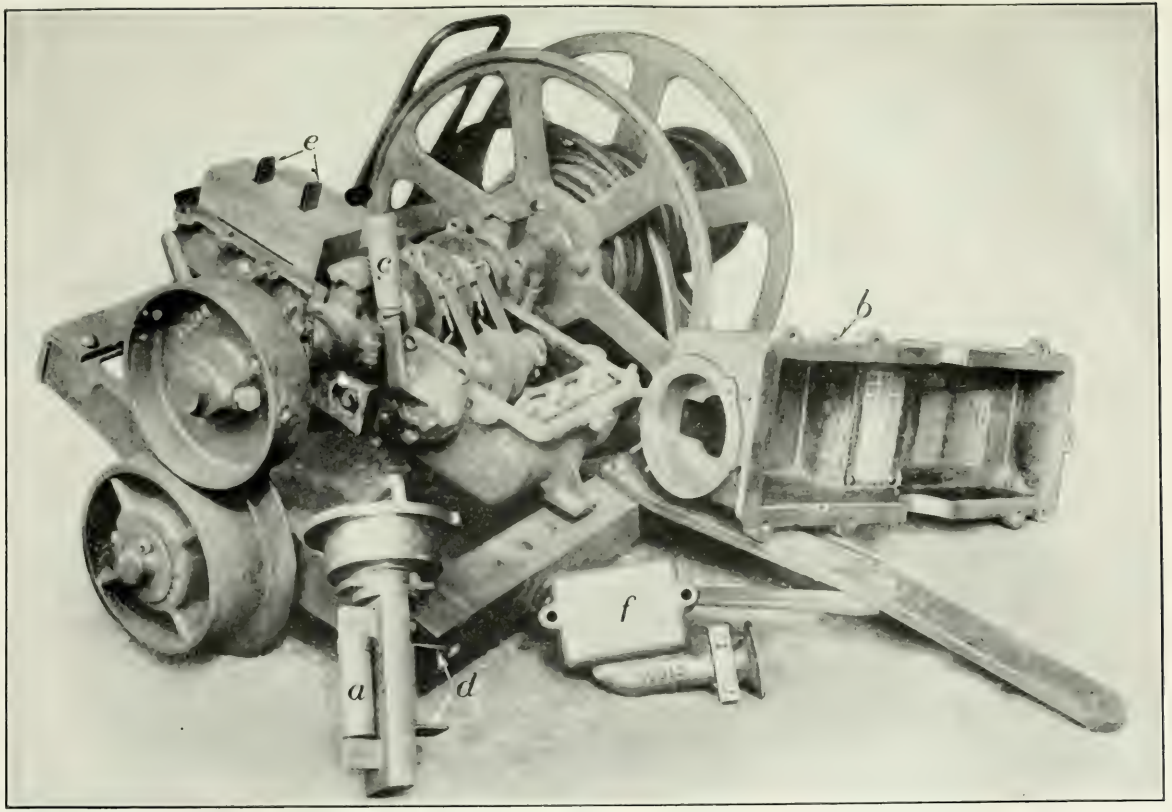
The explosion-proof compartment on the cable-reel truck has a protective device (Pl. IX, *g*) of the same type as the ones used in the machine. The discharge from this device is also downward.

The protective devices each consist of 24 layers of 32 mesh brass gauze made of No. 22 (B. & S. gage) wire. These are supported and spaced by means of 25 grids or punchings from No. 16 (U. S. gage) sheet steel.

All joints between the covers and the various compartments have broad flanges, which are well secured with studs or bolts with bottomed holes.

The inclosure of the switch and fuse in an explosion-proof compartment on the cable-reel truck eliminates the danger of external ignition of fire damp by sparks or flashes that are common when the circuit is opened. The fuse plug can not be withdrawn from the explosion-proof compartment unless it is first turned 90°. This turning disconnects the fuse from the circuit and at the same time insures a broad flange between the casing and the head of the fuse plug when the circuit is opened.

The wiring between the motor, the controller, and the rheostat compartments is within the machine proper and thus is well pro-



GOODMAN 23-C DIRECT-CURRENT CABLE WHEEL AND TRUCK, EXPLOSION-PROOF COMPARTMENT OPEN TO SHOW UNDERSIDE OF PROTECTIVE DEVICE GRID AND DETAILS OF SWITCH AND FUSE.

tected. The trailing cables are protected at the entrances to the machines and cable reels by bell-mouthed bushings and insulated strain clamps.

INVESTIGATION OF 210-VOLT EQUIPMENT.

A 210-volt equipment comprising a motor, controller, rheostat, and a cable reel mounted on its truck was submitted for the investigation.

PRELIMINARY INSPECTION AND RECOMMENDATIONS.

The following recommendations were made after the preliminary inspection: That the fuse box or the motor frame and the flexible metallic tubing on the trailing cables be eliminated; that the protective devices be shrouded, and that greater care be taken to insure no unbottomed holes in explosion-proof casings.

NATURE OF TESTS.

The tests of this machine were made with the motor running, and 7 and 8.6 per cent of gas were used both with and without coal dust. The switch compartment of the cable reel was subjected to the same tests as the compartments of the machine.

A special series of tests was made to determine the effect of stopping off the exhaust ports of the protective devices and also the effect of raising the cover of the commutator pit slightly.

The cable-reel switch was opened and closed under full-load current to determine whether flashing over or dangerous burning of the contacts would occur.

EXPLOSION PRESSURES OBTAINED.

The maximum indicated pressures for the machine as first submitted were as follows:

Maximum pressures for machine as submitted.

In the motor compartment	86.3 pounds per square inch.
In the controller compartment	87.5 pounds per square inch.
In the resistance compartment	Tests not made.
In the cable-reel switch compartment	5.0 pounds per square inch.

The pressures ran about 15 per cent higher with the exhaust ports closed.

After the machine was altered to conform to the final designs the maximum indicated pressures were:

Maximum pressures after changes.

In the motor compartment	76.7 pounds per square inch.
In the controller compartment	75.0 pounds per square inch.
In the resistance compartment	103.3 pounds per square inch.

The construction of the cable reel in its final design was essentially the same as the one first submitted, hence no further tests were made.

CHANGES IN DESIGN.

The following important changes in design brought about through inspections and tests were made:

1. Bell-mouthed bushings replaced flexible armor for cable intakes.
2. Insulated strain clamps for cables were provided.
3. The fuse box on the motor was eliminated.
4. Another opening between controller and motor compartments was provided.
5. The outlet from the cable-reel protective device was shrouded to prevent the entrance of dust and dirt.

INVESTIGATION OF 500-VOLT EQUIPMENT.

From an examination of the drawings submitted for the two equipments the engineers in charge of the tests decided that it would only be necessary to determine what effect would be produced upon the pressures with the 500-volt rheostat installed as compared to the pressures with a 210-volt rheostat. The 500-volt rheostat was installed in the 210-volt machine and tests were made with 8.6 per cent gas, no coal dust, and with the motor running. Pressure readings, taken in the rheostat compartment, were found to be slightly less with the higher voltage rheostat than with the lower one. All changes made as a result of the inspection and test of the 210-volt equipment have been incorporated in the 500-volt equipment.

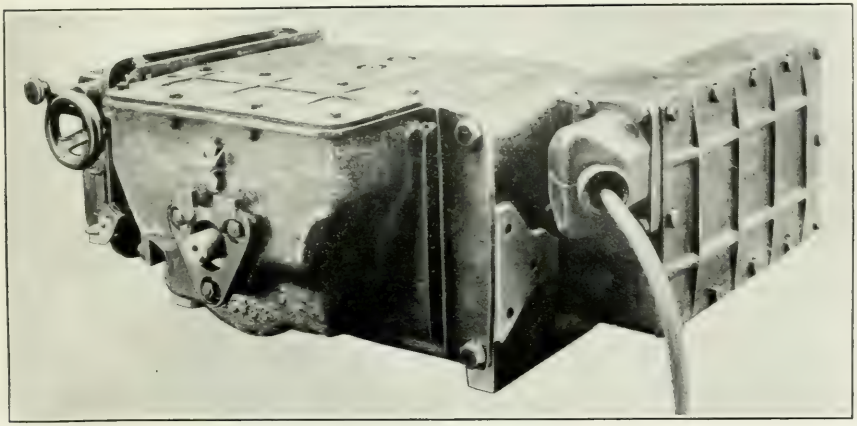
The approval of the 500-volt unit was based chiefly upon the tests of the 210-volt unit.

SUMMARY.

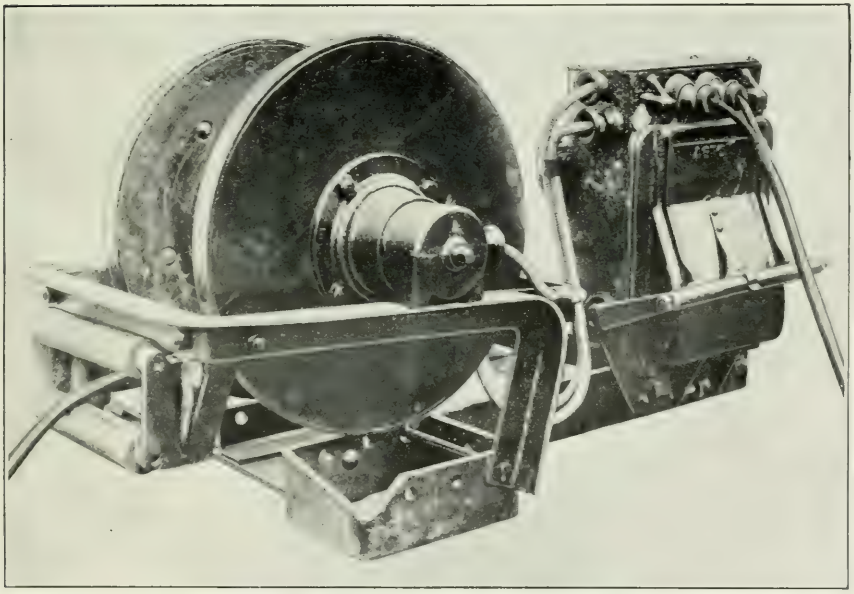
Approvals No. 101 and 101A were both granted May 20, 1916. When constructed in conformity with the machine tested and approved, the 23–C equipments are considered safe units and are recommended for use in gaseous mines.

JEFFREY DIRECT-CURRENT COAL-CUTTING EQUIPMENTS, APPROVALS NO. 102 AND 102A.

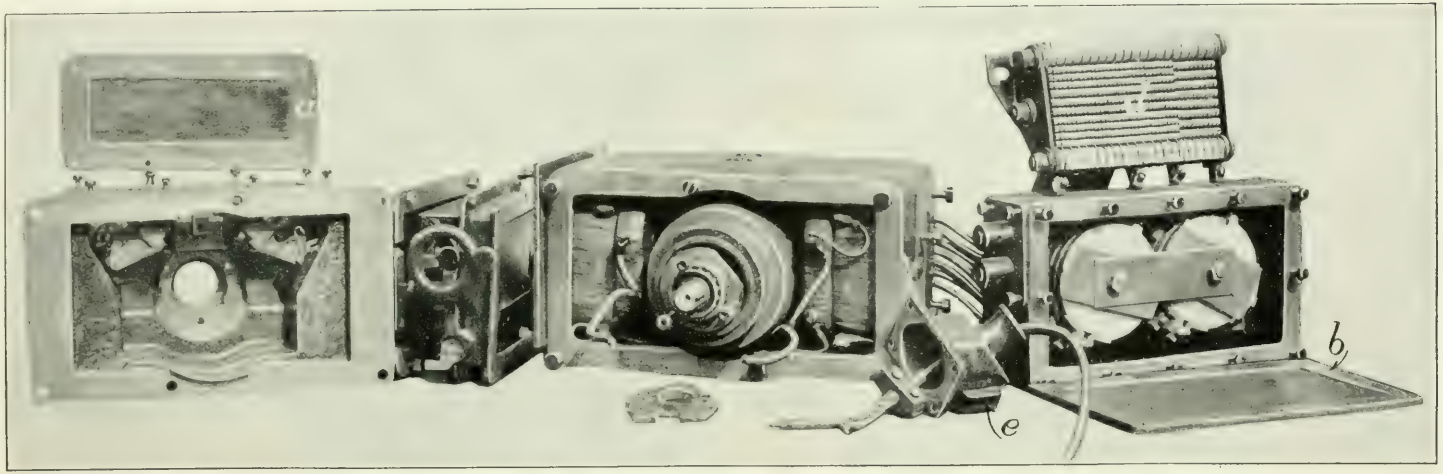
The Jeffrey Manufacturing Co., of Columbus, Ohio, made application under Schedule 2 for the test and approval of a 250-volt and a 500-volt equipment and submitted a 250-volt outfit for inspection and test. The investigation of the 250-volt equipment was held to apply to the higher voltage machine because the mechanical construction for either voltage was practically identical. The company was not required to submit a complete 500-volt unit. A 500-volt rheostat, however, was shipped for inspection.



A. JEFFREY 28A DIRECT-CURRENT MACHINE.



B. JEFFREY CABLE REEL AND SWITCH FOR 28A AND 35B DIRECT-CURRENT MACHINES.



JEFFREY 28A DIRECT-CURRENT MACHINE; DETAILS OF CONSTRUCTION.

DESCRIPTION OF 28A DIRECT-CURRENT EQUIPMENTS.

The equipments covered by this investigation are designated as Type 28A machines for short-wall mining. Approval No. 102 covers the machine which is equipped with a 250-volt motor and No. 102A covers the same type of machine having a 500-volt motor.

The electrical features considered in granting the above approvals were: The motor, the controller, the rheostat, the cable reel and truck with fuse and switch, and the wiring. Plate X, *A*, shows the machine completely assembled and Plate X *.B*, shows an assembled view of the cable reel and truck.

Drawing lists 102 and 102A kept on file with the bureau give the essential details of construction upon which approvals 102 and 102A, respectively, were based.

MOTOR.

The 28A machine uses a direct-current, compound-wound, multipolar motor (Pl. XI, and Pl. XII), designed to give 35 horsepower for one hour without exceeding a temperature rise of 75° C. The cast-steel cover *a* (Pl. XI) is directly over the commutator when the machine is assembled and is easily removed for examination of brushes and commutator.

CONTROLLER AND STARTING RHEOSTAT.

The controller is located in a two-part flanged casing bolted to the casting of the main frame. Plate XII shows one part, *a*, of the casing at the right. The arc barriers, *b*, that separate the contact fingers, are taken out to permit examination of the controller drum, connections, and contacts.

The rheostat is in a separate compartment, *c*, Plate XII, and connection between motor and rheostat are made through the passage, *d*. Plate XI shows the two types of resistance used in 28A machines. The compartment cover *b* has been taken off to show a 500-volt rheostat, *c*, bolted in place. A 250-volt rheostat, *d*, rests upon the top of the compartment. The part *e* protects the insulated studs which connect the power supply to the interior of the machine. This part also has a bell-mouthed bushing to prevent undue abrasion of the cable.

CABLE REEL AND TRUCK WITH FUSE AND SWITCH.

A part of the cable-reel truck is shown in Plate X, *B*. On it are mounted the reel and an explosion-proof fuse and switch compartment.

The details of the explosion-proof compartment inclosing a single-pole switch and a fuse are shown in Plate XIII, *A*. The switch

blade *a* is operated by the handle *b*. The fuse is further inclosed within a rectangular chamber, *g*, built up of noncombustible material. The machine may be entirely disconnected from the circuit by pulling the cable terminal plugs, *c*, from the openings, *d*, but only after the switch has been opened and the flanged cover, *e*, has been let down. The wiring between the cable reel and the fuse and switch compartment is carried in flexible, metallic tubing, *f*.

In Plate XIII, *B*, the fuse and switch compartment is closed and the separate compartment containing terminal connections is open.

SAFETY FEATURES.

All compartments, including the fuse and switch compartment, are totally inclosed and depend on broad flanges for explosion-proof protection. The flanges have been designed to withstand the maximum internal explosion pressure developed and are well secured with ample studs and bolts that have bottomed holes.

The wiring between the motor, the controller, and the rheostat is within the machine and is therefore well protected from mechanical injury. The cable is protected by a bell-mouthed bushing where it enters the main frame and by an insulated strain clamp where it connects with the studs through the explosion-proof casing. Flexible metallic tubing is used to protect the wiring between the cable reel and fuse box.

The terminal plugs of the machine cable can not be withdrawn under load and therefore can not produce dangerous arcs or flashes. They are so interlocked with the switch that the latter must be opened in order to release the cover, which then has to be moved to the right before the plugs are free to be pulled out.

INVESTIGATION OF 250-VOLT EQUIPMENT.

A 250-volt equipment, which included the motor, the controller, the rheostat, and a cable reel with fuse and switch, was submitted for the investigation.

PRELIMINARY INSPECTION AND RECOMMENDATIONS.

The preliminary inspection disclosed certain deficiencies that needed to be remedied, namely—

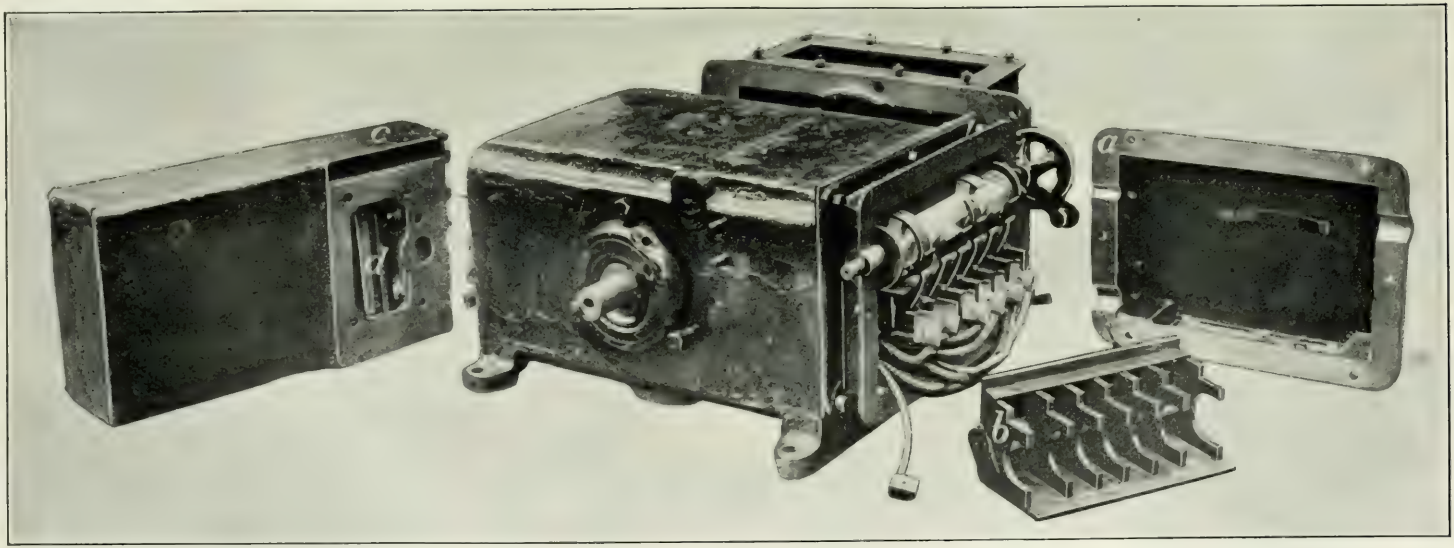
1. Several bolt holes in explosion-proof casings were not bottomed.

2. An insulated cable clamp was not provided with the machine.

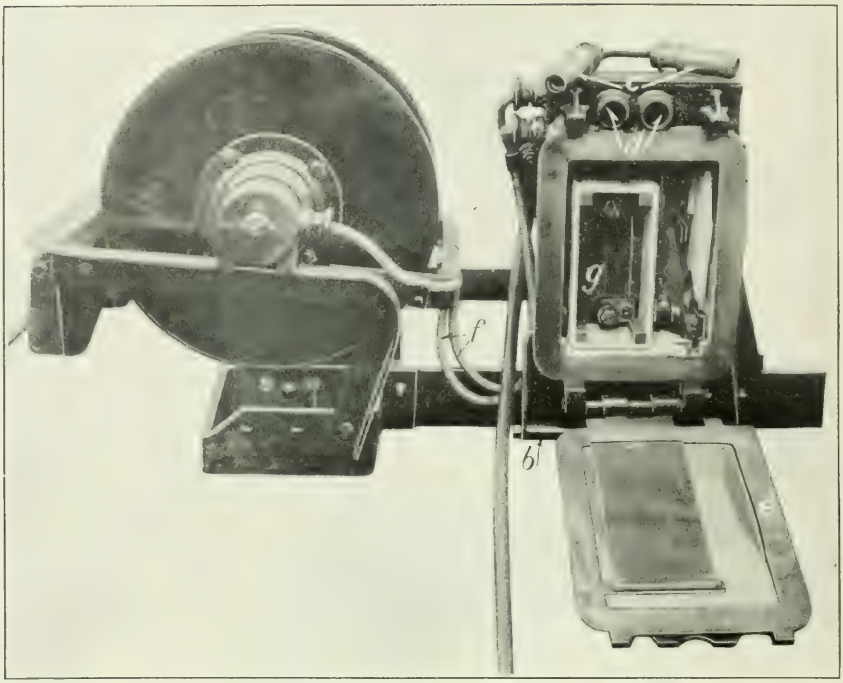
3. Unsuitable material was used for covers of explosion-proof compartments.

4. Several modifications in the fuse box were necessary.

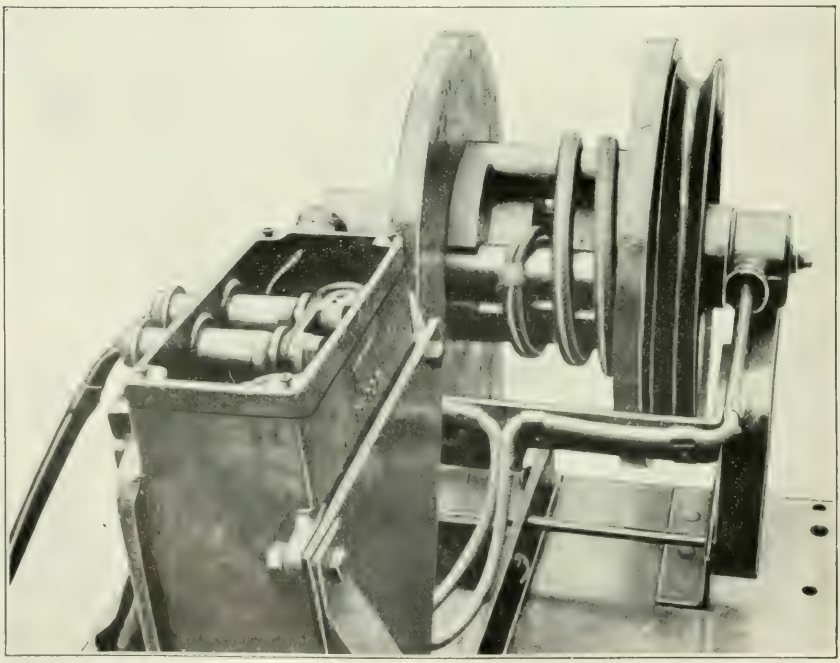
Recommendation was made that the company consider the advisability of the above changes.



JEFFREY 28A DIRECT-CURRENT MACHINE; FURTHER DETAILS OF CONSTRUCTION.



A. JEFFREY 28A AND 35B DIRECT-CURRENT CABLE REEL AND SWITCH; COMPARTMENT FOR SWITCH WITH FUSE OPEN FOR INSPECTION.



B. JEFFREY 28A AND 35B DIRECT-CURRENT CABLE REEL AND SWITCH; TERMINAL COMPARTMENT OPEN FOR INSPECTION.

NATURE OF TESTS.

In the tests upon the machine proper the motor was running and 7 and 8.6 percentages of gas were used. The fuse and switch compartments attached to the reel truck were tested with 8.6 per cent gas.

EXPLOSION PRESSURES OBTAINED.

The maximum indicated pressures for the tests were as follows:

Maximum indicated pressures.

In the motor compartment	73. 3 pounds per square inch.
In the controller compartment	66. 6 pounds per square inch.
In the resistance compartment	33. 3 pounds per square inch.
In the fuse compartment	19. 3 pounds per square inch.

As the changes made in the design had no bearing on explosion pressures developed, the original pressures stand as representative of the equipment approved.

CHANGES IN DESIGN.

As a result of recommendations and tests made by the bureau certain minor changes in design were made, namely—

1. Covers of explosion-proof chambers were made of cast steel instead of boiler plate.
2. Castings were modified to eliminate unbottomed holes in explosion-proof casings.
3. Flanges were made wider.
4. An insulated strain clamp was provided to relieve the strain on the hand cable connecting the reel and the machine.
5. The arrangement of the insulating barriers in the fuse box was changed to make the fuse more accessible for renewals and to inclose the fuse completely.

INVESTIGATION OF 500-VOLT EQUIPMENT.

A careful study of the drawings submitted showed that mechanically the 28A machine was the same for either voltage. A repetition of inspection was therefore unnecessary for the higher voltage equipment. The space occupied by the rheostat units was practically the same for either voltage, hence as regards explosion-proof protection another set of tests was not required.

All changes in mechanical construction which were made in the interests of safety and for improvement during the investigation of the 250-volt machine were embodied in the 500-volt machine.

Approval No. 102A was granted principally upon the basis of the investigation of the 250-volt equipment, which met the requirements of the schedule.

SUMMARY.

Approvals No. 102 and No. 102A were issued November 2, 1917. When constructed in conformity with the machine tested and approved, the 28A equipments are considered safe units and are recommended for use in gaseous mines.

JEFFREY DIRECT-CURRENT COAL-CUTTING EQUIPMENTS, APPROVALS NO. 103 AND 103A.

The Jeffrey Manufacturing Co., of Columbus, Ohio, also applied under Schedule 2 for the test and approval of a second type of direct-current equipment in two voltages, and submitted a machine equipped with a 250-volt motor for inspection and test. Because the 500-volt equipment was practically the same in mechanical construction as the lower voltage equipment, one set of inspections and tests was held to be sufficient for both voltages.

DESCRIPTION OF 35B DIRECT-CURRENT EQUIPMENTS.

The equipments covered by this investigation are known as Type 35B, short-wall mining machines. The 250-volt direct-current equipment was assigned approval No. 103 and the 500-volt equipment approval No. 103A.

The motor, the controller, the rheostat, the cable reel, and truck with fuse and switch, and the wiring were the electrical parts considered in granting the above approvals. The one design of controller, resistances, and cable reel, fuse, and switch is used for either the 28A or 35B machines. Plate XIV, *A*, shows an assembled view of the machine proper, and Plate X, *B*, the cable-reel truck with reel, fuse, and switch.

Drawing lists 103 and 103A kept on file with the bureau give the essential details of construction upon which approvals 103 and 103A, respectively, were based.

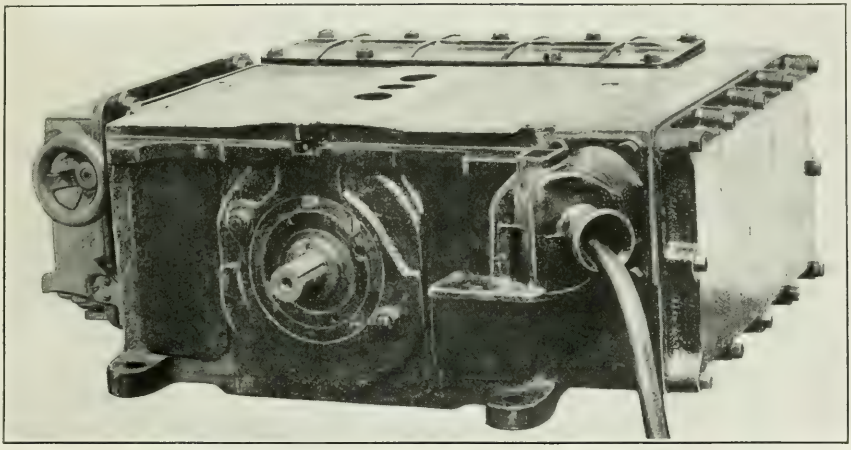
MOTOR.

The 35B equipment is operated by a compound-wound multipolar motor designed to deliver 35 horsepower for one hour, without exceeding a temperature rise of 75° C. The removable cast-steel cover *a* (Pl. XV) gives ready access to the commutator and brush holders.

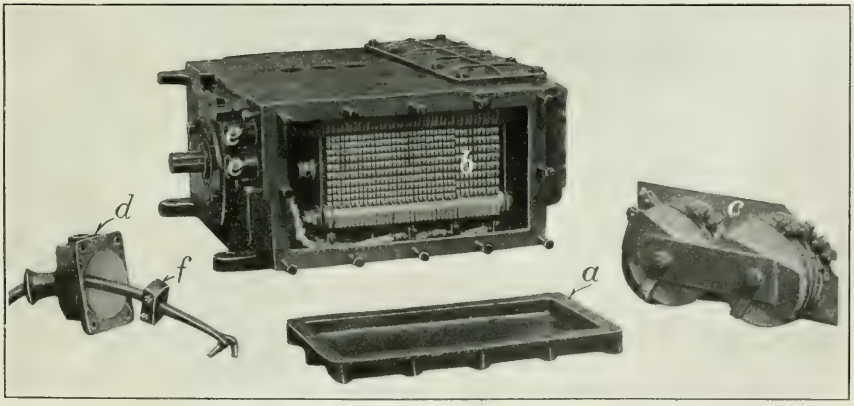
CONTROLLER AND STARTING RHEOSTAT.

Plate XV also gives a dissembled view of the type of controller that is common to the 28A and 35B machines. The controller drum is operated by the handwheel *b*, the reversing switch by the handle *c*.

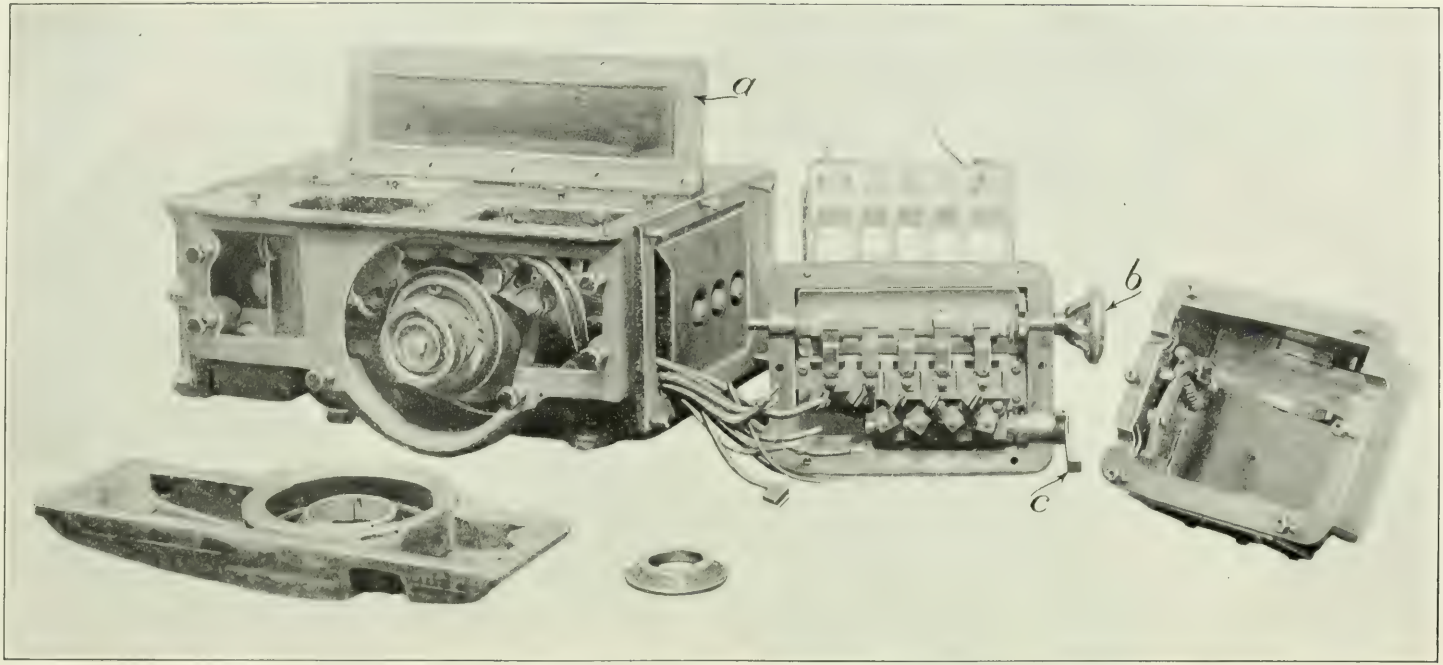
In the 35B machines the rheostat is placed in a compartment which is embodied in the main frame. Plate XIV, *B*, shows the



A. JEFFREY 35B DIRECT-CURRENT MACHINE.



B. JEFFREY 35B DIRECT-CURRENT MACHINE, RHEOSTAT COMPARTMENT OPEN FOR INSPECTION.



JEFFREY 35B DIRECT-CURRENT MACHINE, MOTOR AND CONTROLLER COMPARTMENTS OPEN FOR INSPECTION.

rheostats for both voltages. The cover *a* of the resistance compartment is removed to show the 250-volt rheostat *b* in position. The rheostat *c* at the right replaces the 250-volt rheostat when the machine is built for 500-volt service. The casting *d* protects the insulated studs *e*, by which power is supplied to the machine through the resistance compartment. The insulated clamp *f* relieves the studs of strain. A bell-mouthed bushing forms a part of the casting *d*.

CABLE REEL AND TRUCK WITH FUSE AND SWITCH.

These parts have already been described for the 28A machine and are shown in Plates X, *B*, and XIII, *A* and *B*.

SAFETY FEATURES.

The 35B machine uses the totally inclosed form of construction with broad flanges. The flange joints are held together securely with ample bolts and studs, which have bottomed holes. The flanges and casings are properly proportioned for the maximum internal explosion pressures that may develop.

The wiring between the motor, the controller, and the rheostat is inclosed in the casings and is well protected from mechanical injury. Where the cable enters the machine a bell-mouthed bushing minimizes abrasion. The wiring between the cable reel and the fuse box is run in flexible, metallic tubing for protection.

The terminal plugs on the machine cable are interlocked with the switch in the explosion-proof compartment in order to prevent arcs and flashes from being drawn into the atmosphere when the plugs are removed. The switch must first be opened and the cover of the compartment moved to the right before the plugs can be withdrawn. The switch can not be closed unless the cover is in its proper position.

INVESTIGATION OF 250-VOLT EQUIPMENT.

The Jeffrey Manufacturing Co. originally submitted its 35B machine with the plate type of protective devices. An investigation, including inspection and several series of tests, had been made of the machine in this form, when its return to the factory for modification became necessary.

While at the factory the use of protective devices was abandoned, and the machine was rebuilt in the totally inclosed form and resubmitted for test and approval. One cable-reel truck with reel, fuse, and switch was submitted for the investigation of both the 28A and 35B equipments.

PRELIMINARY INSPECTION AND RECOMMENDATIONS.

The initial inspection of the totally inclosed form of 35B machine showed several unsatisfactory details of construction. Recom-

mendations as to modifications in design, however, were withheld until the tests were completed.

NATURE OF TESTS.

The machine with its motor, resistance and controller compartments was tested in 8.6 per cent of gas. The effect of closing off and of opening passages between compartments was studied.

The tests of the cable reel are reported under the investigation of the 28A machine.

EXPLOSION PRESSURES OBTAINED.

The totally inclosed machine in the form first submitted gave the following maximum, indicated pressures:

Maximum pressures in machine as submitted.

In the motor compartment	60.0 pounds per square inch.
In the controller compartment	over 100.0 pounds per square inch.
In the resistance compartment	No pressures taken.

The maximum indicated pressures for the form finally approved were as follows:

Maximum pressures in machine as approved.

In the motor compartment	62.5 pounds per square inch.
In the controller compartment	65.4 pounds per square inch.
In the resistance compartment	57.4 pounds per square inch.
In the fuse compartment	19.3 pounds per square inch.

CHANGES IN DESIGN.

The changes in design found necessary from inspections and tests are as follows:

1. Flanges were widened.

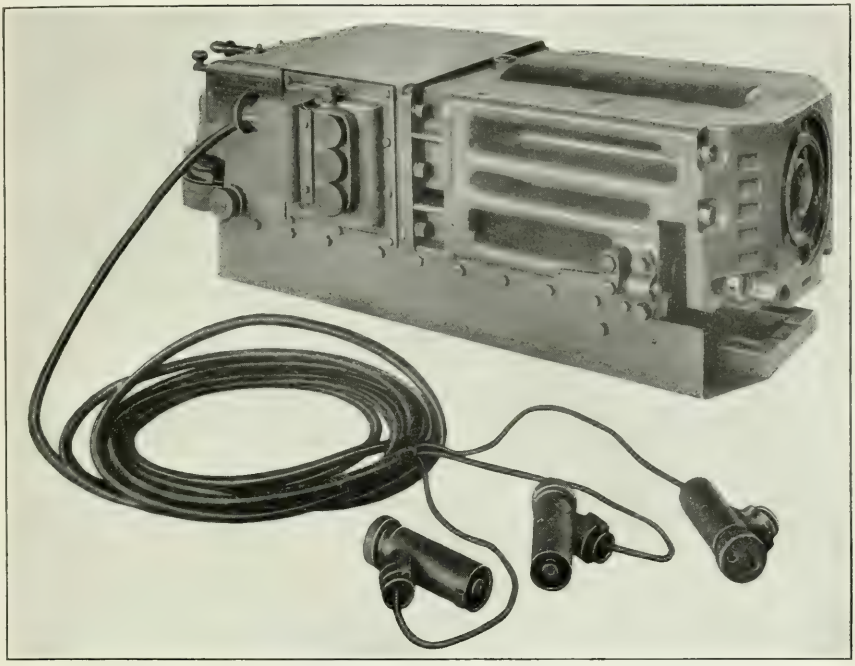
2. The resistance compartment was completely isolated from the motor compartment, and the leads run through specially constructed stuffing boxes packed with asbestos rope.

3. The opening between the motor and the controller compartments was increased.

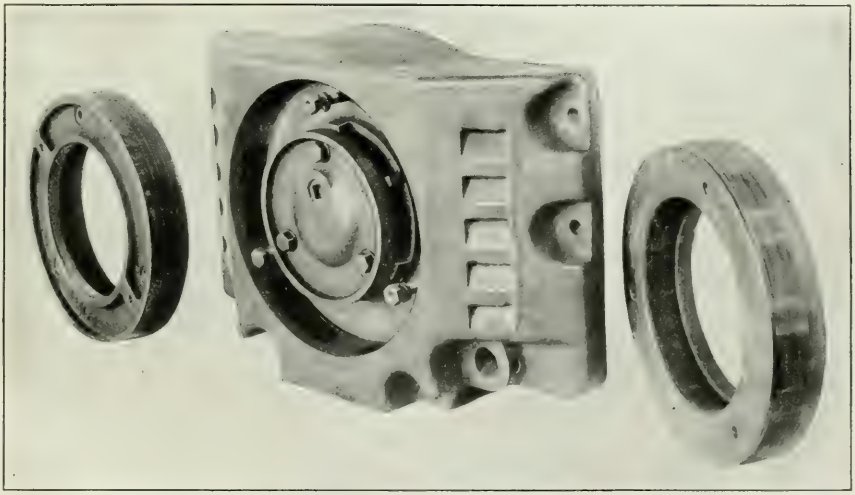
INVESTIGATION OF 500-VOLT EQUIPMENT.

From a careful study of drawings the 500-volt equipment was seen to be mechanically the same as the lower voltage equipment and because of this similarity one set of inspections and tests was considered sufficient for both voltages.

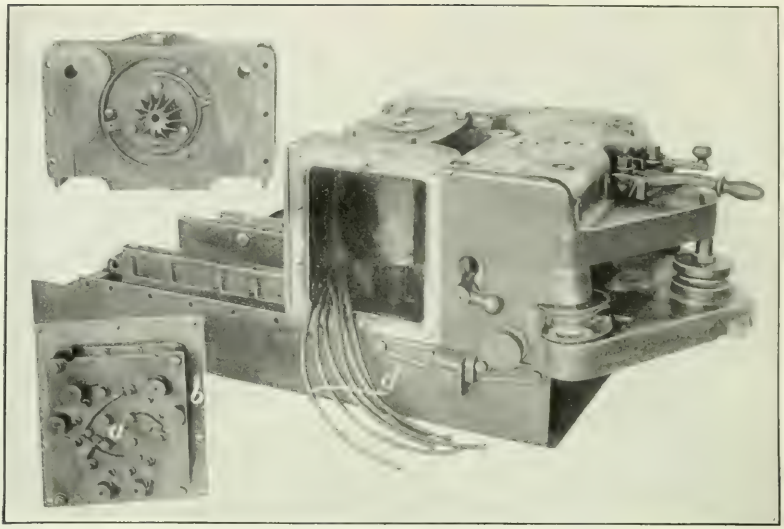
The 500-volt equipment has incorporated in it all the modifications that were made in the 250-volt equipment in the course of the inves-



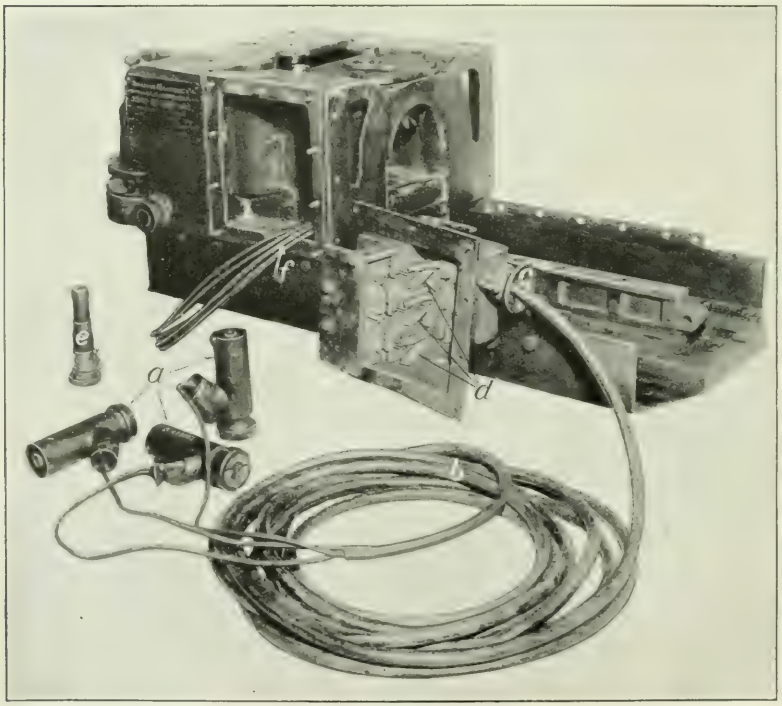
A. SULLIVAN CE-7 ALTERNATING-CURRENT MACHINE.



B. SULLIVAN CE-7 ALTERNATING-CURRENT MACHINE, FRONT HEAD WITH BOTH PROTECTIVE ELEMENTS REMOVED.



A. SULLIVAN CE-7 ALTERNATING-CURRENT MACHINE, MOTOR REMOVED; REAR HEAD IN THE BACKGROUND AND CONTROLLER COMPARTMENT OPEN FOR INSPECTION.



B. SULLIVAN CE-7 ALTERNATING-CURRENT MACHINE; SWITCH AND FUSE COMPARTMENT OPEN FOR INSPECTION.

tigation in order to bring it to the final approved form. Approval No. 103A was based, in the main, upon the investigation of the 250-volt equipment.

SUMMARY.

Approvals No. 103 and No. 103A were issued November 2, 1917. When constructed in conformity with the machine tested and approved, the 35B equipments are considered safe units and are recommended for use in gaseous mines.

SULLIVAN ALTERNATING-CURRENT COAL-CUTTING EQUIPMENTS, APPROVALS NO. 104 AND 104A.

The Sullivan Machinery Co., of Claremont, N. H., also made application under Schedule 2 for the test and approval of a 220-volt and a 440-volt a. c. equipment and submitted a machine built for 440-volt service for inspection and test.

The investigation of the 440-volt equipment was held to apply to the lower voltage outfit, since the mechanical construction for the two voltages was practically identical.

DESCRIPTION OF CE–7 ALTERNATING CURRENT EQUIPMENTS.

The equipments covered by this investigation are designated as Type CE–7 continuous cutting chain machines designed for room and pillar work. Approval No. 104 was assigned to the 220-volt a. c. equipment and approval No. 104A to the 440-volt outfit.

The electrical features considered in this investigation were the motor, the controller, the fuse, the switch, the cable reel, and the wiring. Plate XVI, *A*, gives an assembled view of the machine proper and Plate XVIII, *A*, an assembled view of the cable reel.

Drawing lists 104 and 104A, kept on file with the bureau, give the essential details of construction upon which approvals 104 and 104A, respectively, were based.

MOTOR.

The motor is a squirrel-cage, 3-phase, 60-cycle induction motor designed to deliver 30 horsepower for 1 hour without exceeding a temperature rise of 75° C. The winding of the stator is arranged so that the motor can be started at about half voltage and then thrown to full voltage for operation without rheostat control.

CONTROLLER AND FUSE COMPARTMENTS.

Plate XVII, *A*, shows the machine with motor removed, rear head in background, and controller compartment open for inspection. The controller *a* is fastened to the flanged cover *b*, which in turn is held securely to the main casting by the studs *c*. The controller is pro-

vided with two sets of contacts, one for the starting and one for the running position. The controller wires *d* pass to the fuse compartment on the opposite side of the machine through a narrow passage so proportioned that the wires fit snugly and prevent an explosion from propagating from one compartment to the other.

Plate XVII, *B*, gives a view of the reverse side of the machine and shows the fuse compartment open for inspection. The current leaves the reel by the cable-reel disconnecting plugs *a* and by the hand cable *b* which enters the machine through the bell-mouthed bushing *c*. The current then passes through the three-phase switch *d* to the fuses located on the same cover. One fuse *e* is shown removed from the cover. These fuses are interlocked with the switch so that they can not be removed or inserted unless the switch is open. The cables *f* run from the fuse terminals to the controller.

CABLE REEL.

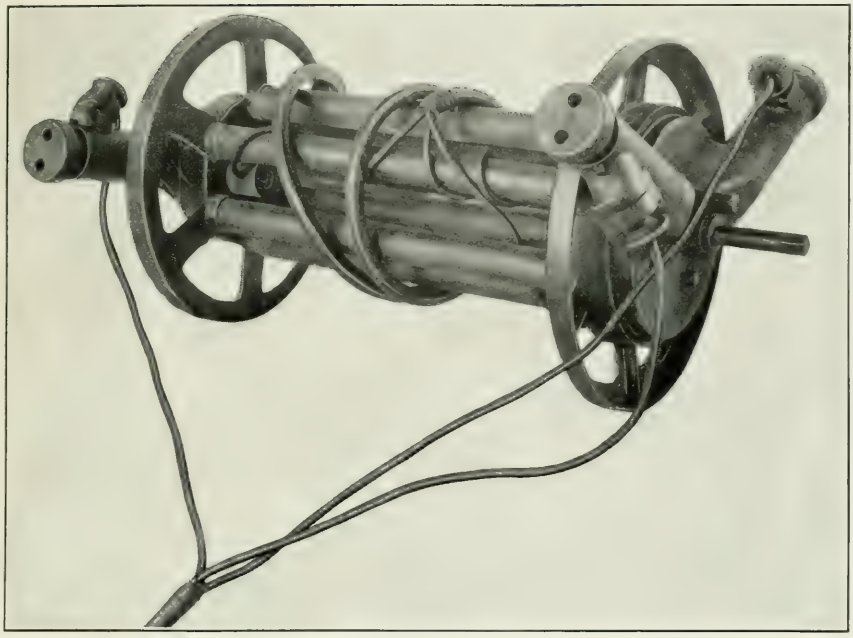
The cable reel is essentially the same as for the d. c. machines previously described, except that it is built for a three-phase instead of a two-wire circuit. Plate XVIII, *B*, shows one end of the three-phase reel dismantled. This view gives clear details of the slip-ring compartment. The trailing cable is connected to the movable contacts *a*, which make contact with the stationary rings *b*. The circuit to the machine is completed by the cable reel disconnecting the plugs *c* and the hand cable *d*. The details of the disconnecting plug have already been described for the d. c. equipment.

SAFETY FEATURES.

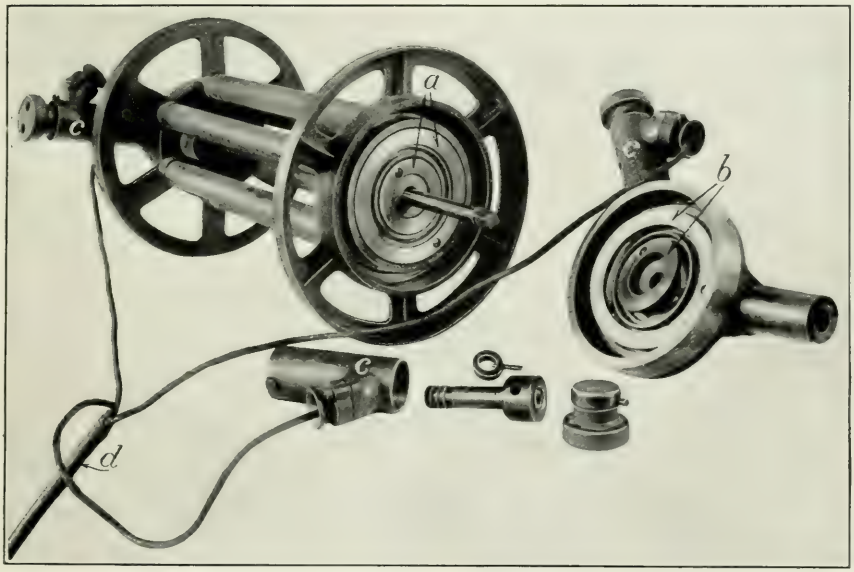
Plate XVI, *B*, shows the front head of the a. c. machine with both elements of the protective device removed. The rear head has two identical elements. The construction of the protective elements is the same as for the d. c. machine, and the paths which the burned gases must traverse when discharged through the devices to the atmosphere is essentially the same as shown in figure 2 for the d. c. machine.

The design of the disconnecting plugs for the reel is common for a. c. and d. c. equipments and therefore should afford the same protection. The three-phase switch is so interlocked with the fuses that they can neither be withdrawn nor inserted unless the switch is open.

The fuse compartment in the a. c. outfits corresponds to the rheostat compartment of the d. c. units. The fuse and controller compartments are practically isolated from each other and from the motor compartment in order to prevent the heaping of pressure caused by the propagation of the explosion from one compartment to another.



A. SULLIVAN CE-7 ALTERNATING-CURRENT CABLE REEL.



B. SULLIVAN CE-7 ALTERNATING-CURRENT CABLE REEL DISMANTLED TO SHOW INTERIOR OF SLIP-RING COMPARTMENT AND DETAILS OF DISCONNECTING PLUG.

The usual precautions have been taken in supplying for all joints between compartments, or for covers of compartments, wide flanges secured with studs or bolts with bottomed holes.

The wiring between the motor, the controller, and the fuse compartments is well protected, as it is run within the machine. The trailing cable is protected from undue abrasion where it enters the fuse compartment and the cable-reel disconnecting plugs by bell-mouthed bushings. Insulated clamps relieve the cable connections of strain in the fuse compartment and in the cable-reel plugs.

INVESTIGATION OF 440-VOLT EQUIPMENT.

The equipment submitted for the investigation consisted of a three-phase, 440-volt motor with controller, fuses, and cable reel.

The machine in its first form failed to pass the tests, and an investigation was made to determine the design best adapted to meet the conditions of the schedule. In the redesigned form that was approved the motor has a double-element protective device of the plate type in both front and rear heads, and the fuse and controller compartments are isolated from each other and from the motor compartment. The cable reel was also redesigned.

PRELIMINARY INSPECTION AND RECOMMENDATIONS.

The preliminary inspection of the original machine showed that the fuses could be withdrawn under load. A recommendation was made that the fuses be locked in some manner to prevent this.

Later in the investigation recommendations were made that the flexible-cable armors should be discarded and bell-mouthed bushings substituted, that the cable-reel disconnecting plugs should be made explosion-proof, and that the location of openings into protective devices should be changed so as to minimize the possibilities of dust entering the devices and machine.

NATURE OF TESTS.

The tests on the machine in the form finally submitted were made with 7 and 8.6 percentages of gas with and without coal dust. The motor was running in nearly all tests. The investigation of the magnetic blow-out type of cable-reel disconnecting plugs furnished with the d. c. machine, approvals 100 and 100A, was held to apply for the three-phase reel, since the plugs were identical in design and since they were formerly tested for 500 volts, whereas only 440 volts would be used on the a. c. reels.

EXPLOSION PRESSURES OBTAINED.

With the machine in the form first submitted the maximum indicated pressures for the different compartments were as follows:

Maximum pressures in machine as submitted.

In the motor compartment	45.0 pounds per square inch.
In the controller compartment	104.8 pounds per square inch.
In the fuse compartment	51.4 pounds per square inch.
In the cable-reel slip-ring compartment	48.3 pounds per square inch.

With the machine in its final form the maximum indicated pressures were:

Maximum pressures in machine in final form.

In the motor compartment	18.0 pounds per square inch.
In the controller compartment	46.5 pounds per square inch.
In the fuse compartment	30.3 pounds per square inch.
In the cable-reel slip-ring compartment	48.3 pounds per square inch.

CHANGES IN DESIGN.

The chief modifications made as a result of the inspection and tests were:

1. Fuses in the machine were made interlocking with a 3-pole switch that must be opened in order that a fuse can be either replaced or taken out.

2. Unbottomed holes were eliminated in explosion-proof casings.

3. The fuse and the controller compartments were isolated from each other and from the motor compartment.

Practical field experience with the CE-7 d. c. equipments, approvals No. 100 and 100A, brought about the following changes in the design of the a. c. machine:

1. Bell-mouthed bushings replaced cable armors of flexible tubing.

2. The discharge ports from protective devices were placed at the sides of the machine instead of at the top.

3. The explosion-proof disconnecting plugs developed for the d. c. cable reel were used on the a. c. cable reel.

INVESTIGATION OF THE 220-VOLT EQUIPMENT.

From a study of the drawings submitted covering the construction of the 220-volt and the 440-volt outfits the inspections and tests of the 440-volt equipment was considered applicable to the 220-volt equipment also, and the latter was not tested. All changes made as a result of the inspection and test of the 440-volt equipment have been incorporated in the 220-volt equipment. In the main, the approval of the 220-volt unit was based upon the investigation of the 440-volt outfit.

SUMMARY.

Approvals No. 104 and No. 104A were issued January 16, 1919. When constructed in conformity with the machine tested and approved, the CE–7, a. c. equipments are considered safe units and are recommended for use in gaseous mines.

RÉSUMÉ.

In being accorded a place in the bureau's permissible list, the foregoing equipments all met the requirements of Schedule 2A:

1. In construction, they are considered rugged enough to stand reasonably severe service. The casings have adequate strength to withstand any internal explosion of fire damp.

2. In those machines having protective devices, these devices have proven under test to be capable of preventing the passage of flames from the interior to the exterior of casings. The design of these devices and their location within the casings afford protection against mechanical injury while in place, and minimize the accumulation of coal dust in openings.

3. Where flanged joints are used in explosion-proof casings these joints have been made wide enough to satisfy the test requirements with respect to the maximum indicated pressures during the explosion tests.

4. The construction of the machines was shown by test to prevent the development of dangerous afterburning.

The bureau recommends all approved equipments for use in mines where fire damp may accumulate.

The demand for such apparatus will depend mainly on the attitude that the mine owner or person in position to purchase mine equipment has toward safety apparatus. The more the doctrine of "safety first" is practised the greater will be the demand for reasonably safe equipment.

Also, as the operator or responsible official comes more and more to recognize the need of such apparatus and to see in it a safety device he will feel a greater interest in it and will assist the bureau and the manufacturer in keeping it in a safe condition.

During the war there was a tendency, under the stress of the demand for more and still more coal, to disregard safety and the demand for unapproved apparatus was noticeable. When conditions again become normal the bureau looks forward to new and greater interest in safety methods and in safety apparatus.

The bureau has other applications on file and expects that several more coal-cutting equipments will be added to the present list within the next two years. With the list already approved from which to

select, there would seem to be no reason why the operator who wants to safeguard his men can not find a unit that meets his requirements.

The cooperative spirit shown by the various manufacturers whose machines are herein described has been greatly appreciated, and the continuation of such relations between the bureau and those who submit explosion-proof apparatus can but tend to render coal mining safer.

Because both the "open" and permissible or explosion-proof types of coal-cutting machines are on the market the distinction between them may not always be evident from the designation given them by the manufacturer. Permissible equipments, however, can always be distinguished by the Department of the Interior, Bureau of Mines, approval plate, which the manufacturer is required to attach to each approved outfit.

PUBLICATIONS ON COAL MINING.

A limited supply of the following publications of the Bureau of Mines has been printed and is available for free distribution until the edition is exhausted. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

The Bureau of Mines issues a list showing all its publications available for free distribution as well as those obtainable only from the Superintendent of Documents, Government Printing Office, on payment of the price of printing. Interested persons should apply to the Director, Bureau of Mines, for a copy of the latest list.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

BULLETIN 17. A primer on explosives for coal miners, by C. E. Monroe and Clarence Hall. 1911. 61 pp., 10 pls., 12 figs.

BULLETIN 20. The explosibility of coal dust, by G. S. Rice, with chapters by J. C. W. Frazer, Axel Larsen, Frank Haas, and Carl Scholz. 1911. 204 pp., 14 pls., 28 figs.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs. 20 cents.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1912. 33 pp., 8 pls., 5 figs.

BULLETIN 46. An investigation of explosion-proof mine motors, by H. H. Clark. 1912. 44 pp., 6 pls., 14 figs.

BULLETIN 48. The selection of explosives used in engineering and mining operations, by Clarence Hall and S. P. Howell. 1914. 50 pp., 3 pls., 7 figs.

BULLETIN 50. A laboratory study of the inflammability of coal dust, by J. C. W. Frazer, E. J. Hoffman, and L. A. Scholl, jr. 1913. 60 pp., 95 figs.

BULLETIN 52. Ignition of mine gases by the filaments of incandescent electric lamps, by H. H. Clark and L. C. Ilsley. 1913. 31 pp., 6 pls., 2 figs.

BULLETIN 56. First series of coal-dust explosion tests in the experimental mine, by G. S. Rice, L. M. Jones, J. K. Clement, and W. L. Egy. 1913. 115 pp., 12 pls., 28 figs.

BULLETIN 57. Safety and efficiency in mine tunneling, by D. W. Brunton and J. A. Davis. 1914. 271 pp., 6 pls., 45 figs.

BULLETIN 60. Hydraulic mine filling, its use in the Pennsylvania anthracite fields, a preliminary report, by Charles Enzian. 1913. 77 pp., 3 pls., 12 figs.

BULLETIN 62. National mine rescue and first aid conference, Pittsburgh, Pa., September 23–26, 1912, by H. M. Wilson. 1913. 74 pp.

BULLETIN 68. Electric switches for use in gaseous mines, by H. H. Clark and R. W. Crocker. 1913. 40 pp., 6 pls.

BULLETIN 74. Gasoline mine locomotives in relation to safety and health, by O. P. Hood and R. H. Kudlich, with a chapter on methods of analyzing exhaust gases, by G. A. Burrell. 1915. 84 pp., 3 pls., 27 figs.

BULLETIN 90. Abstracts of current decisions on mines and mining, December, 1913, to September, 1914, by J. W. Thompson. 1915. 176 pp.

BULLETIN 93. Miners' nystagmus, by F. L. Hoffman. 1916. 67 pp.

BULLETIN 99. Mine-ventilation stoppings, with especial reference to coal mines in Illinois, by R. Y. Williams. 1915. 30 pp., 4 pls., 4 figs.

BULLETIN 101. Abstracts of current decisions on mines and mining, October, 1914, to April, 1915, by J. W. Thompson. 1915. 138 pp.

BULLETIN 102. The inflammability of Illinois coal dusts, by J. K. Clement and L. A. Scholl, jr., 1916. 74 pp., 5 pls., 22 figs.

BULLETIN 105. Black damp in mines, by G. A. Burrell, I. W. Robertson, and G. G. Oberfell. 1916. 92 pp.

BULLETIN 118. Abstracts of current decisions on mines and mining, October to December, 1915, by J. W. Thompson. 1916. 74 pp.

BULLETIN 126. Abstracts of current decisions on mines and mining, January to April, 1916, by J. W. Thompson. 1916. 90 pp.

BULLETIN 131. Approved electric lamps for miners, by H. H. Clark. 1917. 59 pp., 17 pls., 7 figs.

BULLETIN 137. The use of permissible explosives in the coal mines of Illinois, by J. R. Flemming and J. W. Koster. 1917. 110 pp., 8 pls., 17 figs.

TECHNICAL PAPER 2. The escape of gas from coal, by H. C. Porter and F. K. Ovitz. 1911. 14 pp., 1 fig.

TECHNICAL PAPER 11. The use of mice and birds for detecting carbon monoxide after mine fires and explosions, by G. A. Burrell. 1912. 15 pp.

TECHNICAL PAPER 17. The effect of stemming on the efficiency of explosives, by W. O. Snelling and Clarence Hall. 1912. 20 pp., 11 figs. 5 cents.

TECHNICAL PAPER 19. The factor of safety in mine electric installations, by H. H. Clark. 1912. 14 pp.

TECHNICAL PAPER 21. The prevention of mine explosions, report and recommendations, by Victor Watteyne, Carl Meissner, and Arthur Desborough. 1912. 12 pp.

TECHNICAL PAPER 23. Ignition of mine gas by miniature electric lamps with tungsten filaments, by H. H. Clark. 1912. 5 pp.

TECHNICAL PAPER 28. Ignition of mine gas by standard incandescent lamps, by H. H. Clark. 1912. 6 pp.

TECHNICAL PAPER 43. The effect of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

TECHNICAL PAPER 44. Safety electric switches for mines, by H. H. Clark. 1913. 8 pp.

TECHNICAL PAPER 62. Relative effects of carbon monoxide on small animals, by G. A. Burrell, F. M. Seibert, and I. W. Robertson. 1914. 23 pp.

TECHNICAL PAPER 75. Permissible electric lamps for miners, by H. H. Clark. 1914. 21 pp., 3 figs.

TECHNICAL PAPER 82. Oxygen mine rescue apparatus and physiological effects on users, by Yandell Henderson and J. W. Paul. 1917. 102 pp., 5 pls., 6 figs.

TECHNICAL PAPER 84. Methods of preventing and limiting explosions in coal mines, by G. S. Rice and L. M. Jones. 1915. 50 pp., 14 pls., 5 figs.

TECHNICAL PAPER 100. Permissible explosives tested prior to March 1, 1915, by S. P. Howell. 1915. 16 pp.

TECHNICAL PAPER 103. Organizing and conducting safety work in mines, by H. M. Wilson and J. R. Fleming. 1917. 57 pp., 35 figs.

TECHNICAL PAPER 108. Shot firing in coal mines by electricity controlled from the outside, by H. H. Clark, N. V. Breth, and C. M. Means. 1915. 36 pp.

TECHNICAL PAPER 112. The explosibility of acetylene, by G. A. Burrell and G. G. Oberfell. 1915. 15 pp.

TECHNICAL PAPER 119. The limits of inflammability of mixtures of methane and air, by G. A. Burrell and G. G. Oberfell. 1915. 30 pp., 4 figs.

TECHNICAL PAPER 121. Effects of temperature and pressure on the explosibility of methane-air mixtures, by G. A. Burrell and I. W. Robertson. 1916. 14 pp., 3 figs.

TECHNICAL PAPER 122. Effects of oxygen deficiency on small animals and on men, by G. A. Burrell and G. G. Oberfell. 1915. 12 pp.

TECHNICAL PAPER 132. Underground latrines for mines, by J. H. White. 1916. 23 pp., 2 pls., 7 figs.

TECHNICAL PAPER 134. Explosibility of gases from mine fires, by G. A. Burrell and G. G. Oberfell. 1916. 31 pp., 1 fig.

TECHNICAL PAPER 138. Suggested safety rules for installing and using electrical equipment in bituminous coal mines, by H. H. Clark and C. M. Means. 1917. 36 pp.

TECHNICAL PAPER 169. Permissible explosives tested prior to January 1, 1917, by S. P. Howell. 1917. 19 pp.

TECHNICAL PAPER 174. Suggestions for the safe operation of gasoline engines in mines, by R. H. Kudlich and Edwin Higgins. 1917. 19 pp., 3 figs.

TECHNICAL PAPER 226. Men who received Bureau of Mines certificates of mine rescue training, compiled by D. J. Parker. 1919. 72 pp.

MINERS' CIRCULAR 4. The use and care of mine rescue breathing apparatus, by J. W. Paul. 1911. 24 pp., 5 figs. 5 cents.

MINERS' CIRCULAR 5. Electrical accidents in mines, their causes and prevention, by H. H. Clark, W. D. Roberts, L. C. Ilsley, and H. F. Randolph. 1911. 10 pp., 3 pls.

MINERS' CIRCULAR 7. Use and misuse of explosives in coal mining, by J. J. Rutledge, with a preface by J. A. Holmes. 1913. 52 pp., 8 figs.

MINERS' CIRCULAR 9. Accidents from falls of roof and coal, by G. S. Rice. 1912. 16 pp.

MINERS' CIRCULAR 10. Mine fires and how to fight them, by J. W. Paul. 1912. 14 pp.

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